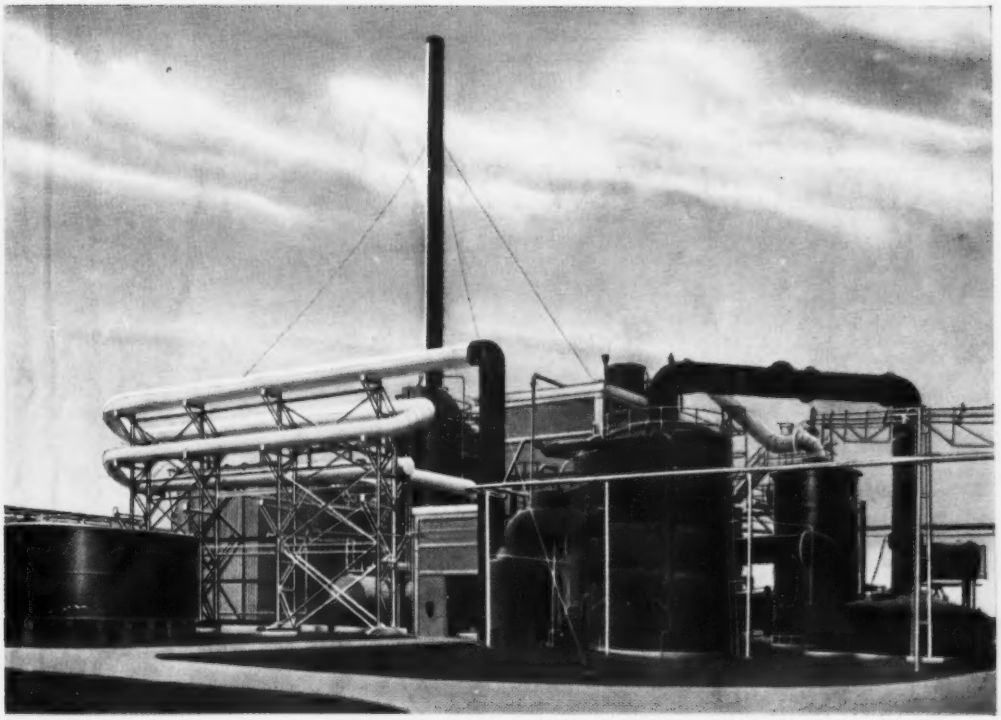

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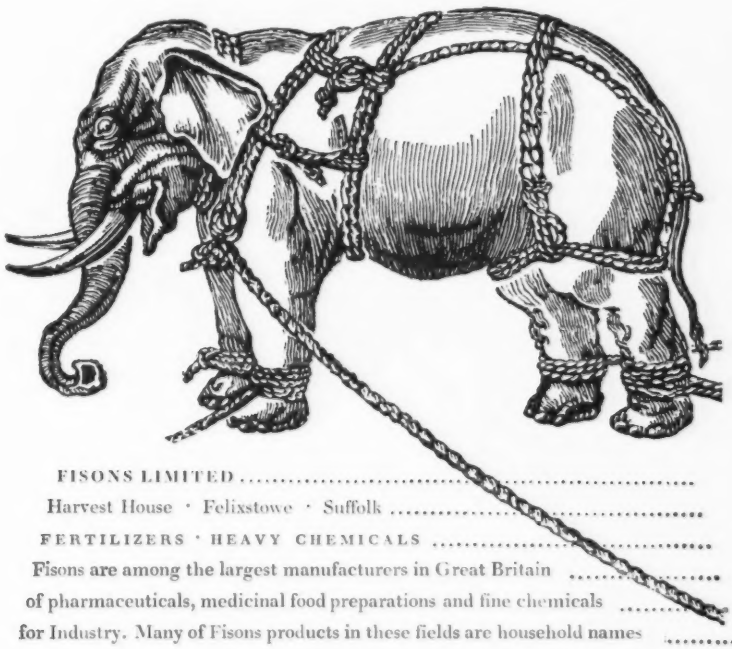

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REVIEW

THE sulphur industry of **Spain** is based on deposits of iron and copper pyrites which extend across the province of Huelva in a belt 80 miles long and 20 miles wide. One of the largest in the world, their proved and probable reserves are estimated to contain 180 million tons sulphur in pyrites. Over the past 90 years more than 60 million tons sulphur have been extracted, 85% of which have been exported to meet the needs of sulphuric acid industries in many parts of the world notably those of the U.K., Western Europe and U.S.A. Spain has further sulphur resources in the form of native deposits of low-grade ores and in complex ores containing zinc blende, galena and pyrites. Domestic sulphur requirements which have increased by about two-thirds in the past five years are at present 340,000 tons, of which 83% is used in the form of pyrites for sulphuric acid manufacture, 4% recovered from zinc smelter gases as by-product sulphuric acid and 13% is elemental sulphur.

Pyritic smelting by the Orkla process provides about 35,000 tons elemental sulphur annually, refining of native ores 4,000 tons and up to 10,000 tons is imported. The start of operation this year of a 30,000 ton recovery plant of sulphur in pyrites roaster and zinc smelter gases will raise indigenous supplies to meet all requirements. The sulphuric acid industry has plans to expand its present capacity of about one million tons (100% H_2SO_4), of which in 1954 77% was employed, by about 800,000 tons. Nearly one-half of the new supplies are destined for ammonium sulphate manufacture and a large proportion of the balance for additional superphosphate manufacture which at present already accounts for 60% of total consumption. The realisation of these plans would, if unaccompanied by a corresponding increase in pyrites production, materially alter the basis of Spain's pyrites industry, the size of which in the past has been determined by its export markets. In 1954 production of 1·9 million tons iron and copper pyrites, supplemented by 0·3 million tons washed pyrites, was conditioned by an export volume of 1·5 million tons.

This level of production and exports—about 40% of that in earlier peak years—is the result of the impact on former markets of other European pyrites supplies, increased use of indigenous sulphur resources, political changes in Europe and the expansion of brimstone use in sulphuric acid manufacture which was only checked by the sulphur crisis of 1951.

The future of the Spanish pyrites industry, if it is to continue its present rôle as the largest exporter in the world, is thought to depend on its ability to reverse the adverse trend of the cost of sulphur in pyrites compared with other sulphurous raw materials and to this end the recent developments in dissociating the sulphur and metal contents of pyrites may provide the ultimate means for the economic use of the country's great sulphur wealth.

The sulphur industry of **Yugoslavia,** potentially one of the largest in Europe, is wholly dependent on the scope and activities of the country's non-ferrous ore and metal industry, since its supplies arise in the form of pyrites concentrates recovered in the course of treating copper, lead and zinc sulphide ores and as sulphur in corresponding smelter gases. At present sulphur production totals only 85,000 tons, of which 98% are in the form of pyrites concentrates and the balance recovered as by-product acid from zinc smelter gases. The domestic sulphuric acid industry in 1954 produced 60,000 tons (100% H_2SO_4) which, although more than four times as much as in 1939, is inadequate to meet the rapidly growing needs of the country. Whereas, given plant facilities, these can be met from existing indigenous pyrites resources—at present about three-quarters of total pyrites output is exported—the lack of native sulphur supplies or sulphur recovery facilities necessitate the import of all elemental sulphur needs. At present these amount to about 4,000 t.p.a., and on completion of a rayon plant, now under construction, and in view of other growing non-acid uses they are likely to exceed 10,000 tons after 1956.

In the **United States of America,** production of Frasch and recovered sulphur during the second quarter, of 1,419,296 tons, brought output for the first half-year to 2,795,246 tons, 4½% less than during the corresponding period of 1954, notwithstanding the increased output of recovered sulphur, now at an annual rate

exceeding 400,000 tons.

Frasch sulphur output continued to be restricted, largely as a result of producers' policy which, in the view of the record apparent sales of 3,133,769 during the first half-year, 15% more than during the first six months of 1954, succeeded in its aim to reduce stocks. At the end of June stocks of native and recovered sulphur had dropped to under three million tons, the lowest general level since first quarter 1952 and representing a drop of 330,000 tons since June, 1954. Domestic sales received their strongest stimulus from the high rate of activity in the acid using steel, detergent, petroleum and rayon industries whilst heavy consumption in the non-acid range for pulp, rubber and rayon manufacture made itself felt. Exports rose seasonally in the second quarter and the first half-year's total of 759,164 tons was 1½% more than that of the corresponding period of 1954.

The Report of the Chemical Products Committee of **O.E.E.C.** reviews the statistical position of sulphurous raw materials in member countries during 1954. As the result of the easy supply position, notably of elemental sulphur, adequate imports supplemented the total production of 2·89 million tons sulphur in various forms, so that after consumption of 4·67 million tons and the modest exports to non-member countries were met, the overall stock position appears to have improved by about 150,000 tons.

Frasch sulphur production in **Mexico** continues at a daily rate of 1,800-1,900 tons, from the Jaltipan and San Cristobal domes which are worked by the Pan-American and Mexican Gulf Sulphur Companies respectively. A third producer, Gulf Sulphur Corporation, is due to start operations in October with a planned daily output of 350-400 tons.

In the **United Kingdom** consumption of sulphur in various forms during the second quarter amounted to 214,000 tons, 2½% more than during the corresponding period of 1954. The start of operations of the anhydrite acid plant of United Sulphuric Acid Company Limited raised the consumption of this raw material to twice last year's level and resulted in increasing the proportion of indigenous sulphur supplies to 37½% of consumption. Imported pyrites met 27% and imported brimstone 35½% of total use. Sulphuric acid production of 521,900 tons (100% H_2SO_4) was 2% greater than during the second quarter of 1954. The consumption of 522,600 tons acid represents an increase of 3½% mainly as the result of greater requirements in rayon, titanium oxide, and superphosphate manufacture, which more than compensated for the reduced acid use in ammonium sulphate production.

The impact on the acid market in the North-West and the Midlands of anhydrite acid supplies, which since July are being augmented by the output from the Whitehaven plant of Solway Chemicals Ltd., is being felt by established producers of " sales " acid whose supplies are derived from pyrites and elemental sulphur. In consequence, pending the further expansion of acid requirements over the next 12-15 months, the expected removal at the end of this year of Government restrictions on the use and import of acid-sulphur, is likely to reverse the present contraction in its use.

The developments in **Sulphuric Acid Plant Construction** over the past 20 years are reviewed in the light of experience gained by Messrs. Simon-Carves Ltd., of Stockport, Cheshire.

There have been no significant changes in the **world price** as represented by the level of U.S. sulphur prices. In spite of the decreasing proportion of bright sulphur in relation to total supplies, its price has weakened in recent months under pressure of lower effective Chilean prices of comparable quality and the impact on world markets in general of the lower Mexican quotations which at U.S.$26½-28 per ton f.o.b. appear to have settled at up to $3.50 below the U.S. export price for off-colour sulphur. Pressure on U.S. producers to abandon the differential between the domestic and export prices is not expected to have immediate results.

Ample **world supplies** of elemental sulphur are resulting in an increasing number of new acid plant projects based on this raw material. Growing Frasch sulphur supplies from Mexico more than compensate for the recent reduction of U.S. output. Under the stimulus of compensating commodity transactions resulting in effective export prices as low as $18 per metric ton f.o.b., Chilean production promises to reach a new peak. At the same time increased use of indigenous sulphur resources, in particular anhydrite and recovery from oil refinery and natural gases, is apparent throughout the world.

THE SULPHUR INDUSTRY IN SPAIN *

General

BASED on the world's most extensive deposits of pyrites, Spain has been playing a dominant part in supplying the sulphur needs of the major sulphuric acid industries in most parts of the world, but notably those of the U.K. and Western Europe, ever since the commercial exploitation of her pyrites wealth started nearly ninety years ago.

The principal deposits are in the Iberian pyrites belt which, over 20 miles wide in places, extends for about 80 miles from Seville in the east across the province of Huelva to the Guadiana River, and thence into Portugal. Pyrites also occur in conjunction with other metal sulphides, notably zinc blende and galena, in the provinces of Murcia and Santander. In addition to Spain's main sulphur resources in the form of pyrites which, treated by the Orkla process also provide the bulk of Spanish elemental sulphur output, there is a number of low-grade native sulphur deposits and sulphur in lead and zinc smelter gases.

Large-scale exploitation of Spanish pyrites deposits, many of which show traces of having been worked for gold, silver and copper in Phoenician and Roman times, dates from 1868 when the Tharsis Sulphur & Copper Company of Glasgow bought extensive mining concessions from a French firm which in the person of Ernest Deligny had rediscovered these rich deposits in 1853. Soon after, in 1873, the Rio Tinto Company of London obtained the freehold rights of the mines of Rio Tinto, which were to become the largest pyrites producer in the world. Expanding requirements of copper, which was obtained by heap roasting and leaching of rich cupreous pyrites, and the growing demand for pyrites by acid makers in the U.K., Western Europe and the U.S.A. led to the rapid development of these mining properties and of other nearby deposits by Spanish and foreign, primarily French and British, companies. Although none approached the magnitude of the Rio Tinto or the Tharsis operations, most of them over the years made important contributions to domestic and export supplies.

In 1954 Spain produced 1,910,430 tons of iron and copper pyrites, an output exceeded only by Japan. The gradual post-war recovery of pyrites production, which reached its peak in 1952, when 2·15 million tons were produced, still falls short of the output in the years before the first world war and again in the late twenties when it reached 3½ to 3¾ million tons pyrites annually. It is estimated that to date Spain has produced over 60 million tons sulphur in pyrites, of which 85% have been exported. This record of sulphur supply is only surpassed by that of the U.S. Frasch sulphur industry whose output up to the end of 1954 was 108 million tons.

The sulphur using industries of Spain, which in 1954 consumed about 340,000 tons sulphur in various forms, have achieved substantial progress in recent years, both in expansion of sulphuric acid/fertiliser production capacity and the increase and diversification of elemental sulphur use. Acid production in 1954 rose to about 780,000 tons (100% H_2SO_4) and new plant projects, of about 800,000 tons acid, are aimed to raise installed capacity to 1·8 million tons, probably by 1960. About 95% of the sulphur requirements of the acid industry are at present met in the form of pyrites and the balance represents by-product sulphuric acid produced from zinc smelter gases. The elemental sulphur needs—currently about 45,000 tons per annum—primarily of agriculture and the rayon industry but increasingly for rubber compounding, SO_2, sulphites, and other chemicals manufacture, are to a large extent met from indigenous resources, although pending the start of the new plant for the recovery of sulphur from roaster and smelter gases, imports of up to 10,000 tons annually have been necessary in recent years.

The mainstay of the Spanish pyrites industry, its export market, has with the exception of a setback in 1953 steadily expanded since the end of the war, especially

*—We are indebted to the Instituto Nacional de Industrias-Piritas Españolas for information placed at our disposal.

as the result of increased pyrites usage in acid manufacture in the U.K. and Western Europe following the sulphur crisis of 1951. But for this the present-day picture might be less favourable because Spain as the highest cost producer is very vulnerable to market fluctuations, especially in a contracting market. The existing system of differential exchange rates, however, provides the government with some means to mitigate this. In recent years a substantial volume of re-equipment of mines, and expansion of production and treatment plant capacity, has been effected. As in the absence of such measures during the Spanish Civil War and subsequently during World War II a vast backlog had been created, it is unlikely that the recent work will make Spanish pyrites more competitive, particularly in view of the inflationary tendencies of the Spanish economy.

Pyrites Deposits and Production

The principal deposits consist of massive ore bodies generally in the form of great lenses which often lie in the contact zones between slates and intrusive porphyry. A comprehensive review of these deposits, presented to the International Geological Congress in Madrid in 1926, disclosed proved and probable reserves of over 420 million tons pyrites, and indicated the possible existence of further substantial tonnages. It is estimated that to-day at least 180 million tons sulphur in pyrites remain to be extracted.

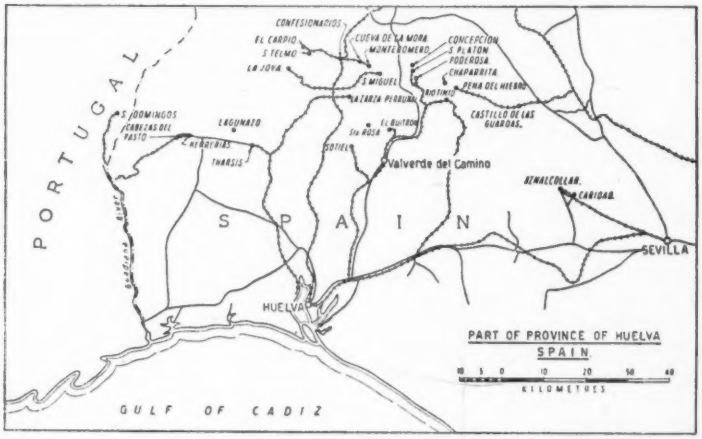


Fig. 1

In addition to iron pyrites there also occur chalcopyrites, cuprocite and other copper ores although the bulk of the high copper ores of secondary enrichment, which formed the upper portions of ore bodies, are now exhausted. A distinctive feature of the formations are the overburden deposits of iron ore and the occasional occurrence of outcrops of gold bearing gossans.

The massive iron pyrites, which account for the bulk of the deposits, contain generally 48-49½% sulphur, 40-44% iron, ½-1% copper and, in addition to non-ferrous metallic impurities, ¼-½% arsenic. A small number of deposits contain purer ore with up to 51% sulphur, e.g. in the San Telmo mass, and there are some with ore of low arsenic content, e.g. San Telmo, Peña, Castillo de las Guardas and Rio Tinto Planes. The occurrence of primary cupreous ores, containing 38-48% sulphur, 1-2½% copper is fairly widespread, though deposits are limited in extent. Complex ores, comprising zinc blende or zinc blende and galena, occur infrequently in the principal pyrites belt but they account for most of the pyrites output in the provinces of Murcia and Santander.

In the early days of exploitation, when the main emphasis was on copper, heap roasting of pyrites in situ was widely practised. This form of extraction was replaced at the turn of the century by a leaching process which did not entail the destruction of pyrites — for which demand was expanding rapidly — whilst permitting the production of cement copper. Many millions of tons of intermediate grades of cupreous pyrites were placed in dumps, in particular at the Rio Tinto Mines where this process was pioneered, and on completion of a minimum leaching cycle of 2½ years for clean ores, washed pyrites containing 48% sulphur became available, involving a weight loss of about 20%. This method continues to be practised to-day at many mines, but on a reduced scale.

The following graph, indicating the level

of pyrites production during the period 1900-1954, emphasises the extent of output being governed by disposal facilities in export markets, and thus the gradual disappearance of the U.S.A. market after 1917, the build-up of U.K. and Western European acid manufacture in the twenties, the pre-war stockpiling by Germany (mitigating the effects of the Spanish Civil War), the war-time isolation and blockade of Spain, post-war European recovery, and finally the increased pyrites usage following the sulphur crisis, are apparent.

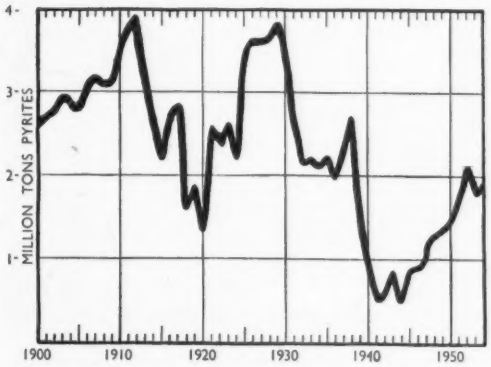


Fig. 2

The distribution of output by individual producers is as follows :—

	Iron Pyrites	*Cupreous Pyrites*	*Total*	*Washed Pyrites*	*Flotation Pyrites*
		Thousand metric tons			
Huelva					
Compañía de Rio Tinto, Ltda.	662.8	144.3	807.1	366.6	—
Compañía de Tharsis, Ltda.	623.2	78.5	701.7	30.2	—
Sociedad Francesa de Piritas	91.0	—	91.0	—	—
Minas de Herrerias, S.A.	79.1	—	79.1	31.0	—
San Telmo Iberica Minera, S.A.	1.0	27.8	28.8	—	5.7
The Peña Copper Mines, Ltd.	5.8	1.7	7.5	2.8	—
Union Española Explosivos, S.A.	13.1	—	13.1	3.3	—
La Joya	16.5	—	16.5	—	—
Concepción	19.1	—	19.1	—	—
Cooperativa La Nava	—	1.6	1.6	—	—
Murcia					
Francisco y Angel Celdrán	62.0	—	62.0	—	—
Zapata Portman	2.3	—	2.3	—	—
Other Mines	8.4	—	8.4	—	—
Santander					
Real Cia. Asturiana de Minas	57.3	—	57.3	—	—
Seville					
Indumental	10.4	—	10.4	—	—
The Seville Sulphur Co.	4.5	—	4.5	—	—
Total 1954 ...	1,656.5	253.9	1,910.4	433.9	5.7
Total 1953 ...	—	—	1,787.9	284.5	12.5

As the result of exhaustion of mines, unprofitable operations due to lack of mechanisation, and transport difficulties, to name only the principal causes, active producers to-day number little more than half compared with, say, thirty years ago. Prominent among earlier foreign producers engaged in supplying their own acid plants at home are United Alkali Limited (now I.C.I.) and St. Gobain. To-day the only representatives of such integrated enterprises are Union Española de Explosivos, Real Cia. Asturiana de Minas and, indirectly, San Telmo.

Compañía Rio Tinto Ltda. The Rio Tinto mines, occupying an area of about 12,000 hectares, consist of four ore bodies, San Dionisio (Atalaya opencast and Alfredo underground), North and South Lodes, and Planes. According to the estimate made in 1926, the Rio Tinto deposits contain 221 million tons proved and probable ore, one of the largest single pyrites reserves in the world. Underground mining is carried out by horizontal cut and fill stoping and sub-level stoping, the latter in the cupreous stockwork. The various mines are connected by two main adit tunnels served by steam and electric railways to transport the extracted ore to the treatment plants. These comprise crushing and screening installations capable of treating 250 tons of crude and washed ores per

Atalaya open cast mine at Rio Tinto

hour, a flotation concentrator with a daily capacity of about 1,500 tons cupreous pyrites and a 200,000 tons per annum heavy media concentrator installed in 1952 to beneficiate low-grade washed ores, accumulated over the years from the leaching of silicious copper ores.

Higher grade cupreous pyrites (1½%-2% Cu) together with copper flotation concentrates have been used since 1930 in the production of elemental sulphur and blister copper by the Orkla process. Pyritic smelting in modified blast furnaces and the reduction of SO_2 by coke yields a low-grade copper matte—which is resmelted and then converted to blister copper —and sulphur vapour. After condensation and dust extraction, the crude liquefied sulphur is cleansed by lime washing of arsenic contamination and after being passed through filter presses is left to solidify, now 99.9% pure. Actual sulphur recoveries rarely exceed 55%, mainly as the result of losses in exit gas and the formation of complex sulphur compounds. At present output totals about 35,000 tons per annum.

In 1954 the company's ore output totalled 807,099 tons, of which 82% were iron pyrites and 18% cupreous pyrites and this was supplemented by 366,570 tons washed ore lifted from cementation heaps. This is substantially below the levels achieved prior to 1930, and represents under 40% of the peak output of 1928. Shipment of pyrites and the bulk of the sulphur and copper output of the mines is effected over the company's pier at Huelva, which is connected with the mine by the company's own railway. Deliveries in 1954 totalled 933,314 tons pyrites of which 251,523 tons accounted for 44% of the domestic market and the balance represented 47% of Spanish export. In addition, the company's own activities for copper and sulphur production absorbed 185,293 tons pyrites.

In 1954 the control of the mine passed from the Rio Tinto Company Limited, London, into the hands of Spanish interests, in return for a capital payment of £7⅔ million spread over three years. Apart from retaining a one-third interest, the former owners have agreed to continue making their technical services available to the new company as well as the established marketing organisation of their London office.

Tharsis Sulphur and Copper Company. This British company, whose head offices are at Glasgow, is at present the second largest pyrites producer in Spain, operating two major deposits, Tharsis and La Zarza. The extent of the deposits which, especially at La Zarza, are often more than 180 metres wide, the hardness of the ore and solidity of the ground surrounding the deposits permit ore extraction in large chambers (30 x 300 metres) without supports. Proved and probable reserves at these two deposits were estimated (1926) to total 154 million tons ore.

The bulk of current production originates from La Zarza but dewatering of the North and Centre Lodes and the opencast at Tharsis are in progress and these deposits, some of which had been abandoned as long as 70 years ago when the copper content of the pyrites became too low for profitable extraction, are now being prepared for large-scale pyrites mining. Given adequate markets, their exploitation and the additional output from La Zarza, where new installations have substantially increased the potential output of ½ million tons, could result in the company becoming the largest single producer.

The mine railway network connects with the Odiel State Railway, which carries the output to the company's pier at Corrales, on the west side of the port of Huelva.

In 1954 the company produced 701,738 tons pyrites, of which about 11% were cupreous, and also lifted 30,241 tons washed pyrites. Shipments amounted to 718,983 tons, of which 190,035 tons accounted for one-third of the domestic market, and the balance represented 36½% of Spanish pyrites exports.

Although none of the smaller producers currently exceed an annual output of 100,000 tons pyrites, their deposits generally contain substantial reserves. *Société Française des Pyrites de Huelva*, of Paris, regular suppliers especially of export markets since 1900, operate the Lomero-Poyatos and Perrunal deposits. Partly as the result of transport difficulties, the present level of output is only about 30% of that achieved in the late twenties, but the high grade of their ore ensures a ready market. *Minas de Herrerias, S.A.*, of Madrid, have operated the Cabezas del Pasto and Guadiana mines since 1949, when the lease agreement with the St. Gobain company was terminated. Extensive re-equipment has raised production capacity to 120,000 tons iron pyrites. The company's shipments are effected through La Laja on the Guadiana River, which is navigable by sea-going vessels of up to 2,000 tons. *San Telmo Iberica Minera, S.A.*, of Bilbao, who are re-equipping their mine mainly with a view to increasing the output of copper, produce both a high grade iron pyrite and pyrites concentrates resulting from the flotation of cupreous pyrites and complex ores. Although present mine capacity is about 90,000 tons per annum, output in 1954 was curtailed by irregular operation of the flotation plant. By the installation of a new shaft and shaft head, and later of a new crushing plant, present capacity is to be doubled.

Due to the lack of markets for the low grade pyrites (40-45% sulphur) produced at the various mines near Carthagena, in the Murcia province, output in 1954 was little more than half that of the previous year. The bulk of the pyrites produced in this region are flotation concentrates resulting from the treatment of complex sulphide ores.

The pyrites output of the Reocin mines of *Real Cia. Asturiana de Minas* of Santander is also a flotation product, but containing 48-49% sulphur. The present output of about 5,000 tons per month, of which about one-half is exported, is due to be increased by at least 20% when the company's new plant at Hinojedo, for the recovery of elemental sulphur from pyrites roaster and zinc smelter gases, is completed, probably this year. It is based on the process developed by the American Smelting and Refining Company (ASARCO) using dimethyl-amine in cold solution, which releases SO_2 on heating. The plant is designed to yield

260 tons per day SO_2, of which 90 tons will be produced in liquid form, and the balance reduced by producer gas. Allowing for normal losses, this would permit the recovery of about 70 tons per day elemental sulphur.

Native Sulphur

The production of native sulphur is at present limited to three producers exploiting deposits mostly of low-grade ores.

Ore refining methods are similar to those practised in Sicily, and Gill furnaces, in some instances modified to suit special conditions, are used.

La Industria Quimica de Zaragoza have been exploiting the deposits at Libros in the province of Teruel since about 1910. In the past twenty years about 1·2 million tons ore, containing 30-60% sulphur, have been extracted and refined in Gill-Claret furnaces, which are fired by the oil content (4-5%) of the bituminous slates found in this deposit. A further deposit of about 600,000 tons of sulphur ore containing 14-25% sulphur awaits exploitation, but, as the existing plant is not suitable for this lower grade material, the installation of new equipment is being considered. Currently the output of their mine, together with crude sulphur purchased from Rio Tinto, is refined at the company's refineries at Libros and Huelva, yielding about 2,400 tons sublimed sulphur, flowers, and other forms of refined sulphur.

Coto Minero de Hellin, S.A., operate a low-grade deposit at Hellin, province of Murcia, and produce at present about 3,000 tons refined sulphur annually. *Azufres de Lorca S.A.* are similarly engaged, and produce up to 1,000 tons per annum refined sulphur at their Lorca (province of Lurcia) refinery.

In 1953, according to official sources, production of native sulphur was as follows :—

	Tons
Coto Minero de Hellin	2,868
La Industria Quimica de Zaragoza ...	564
Azufres de Lorca	674
Total ...	4,106

This output supplemented elemental sulphur produced from pyrites at Rio Tinto, which in 1953 amounted to 33,982 tons.

Smelter Gases

At present only a proportion of sulphur in zinc smelter gases at the works of the Cia. Real Asturiana are recovered as by-product sulphuric acid. It is estimated that in 1954 about 15,000 tons sulphur in acid were recovered, less than half the potential tonnage. The company's sulphur recovery plant due to start operations this year is partly based on zinc smelter gases, and it is expected that total recovery from this source will increase to about 20,000-22,000 tons per annum sulphur.

Production—All Sources

To sum up, the production of sulphur in various forms in 1954 totalled approximately 940,000 tons. The use of pyrites by individual producers in smelting, copper flotation, and leaching, represents a loss of some 90,000 tons sulphur, although part of this is recovered as elemental sulphur produced by the Orkla process and as washed pyrites.

It is estimated that supplies available for delivery totalled about 890,000 tons sulphur, comprising 835,000 tons sulphur in pyrites, 40,000 tons elemental sulphur, of which about 4,000 tons were native refined sulphur, and 15,000 tons sulphur in by-product sulphuric acid, supplemented by 210,000 tons sulphur in the form of washed pyrites.

Consumption

Total consumption of sulphur in all forms in 1954 amounted to about 340,000 tons. Of this, about 45,000 tons were in the form of elemental sulphur, 15,000 tons as sulphur in smelter gases and the balance in the form of pyrites. Since 1949 consumption has risen by about two-thirds, principally on account of increased requirements of the sulphuric acid industry. Further expansion plans of the industry indicate that by 1960 its sulphur requirements for acid manufacture may amount to over 650,000 tons per annum sulphur whereas the sulphur needs of other industries are expected to rise to about 70,000 tons per annum.

" Regular " Sulphur

Of the current consumption of about 45,000 tons, 85%-90% is met from indigenous sources. The present level of elemental sulphur consumption is restricted by inadequate

domestic supplies which, due to limited foreign exchange resources, cannot be fully supplemented by imports. It is anticipated that the entire new production of liquid SO_2 and elemental sulphur by Cia. Real Asturiana will be absorbed by the domestic market as soon as it becomes available. Agriculture, served by a number of small to medium sized establishments engaged in sulphur refining and grinding, takes up about 55% of total elemental sulphur usage. The second largest user is the rayon industry, represented primarily by S.N.I.A.C.E., which absorbs the carbon disulphide output of some twenty-one producers. CS_2 production in 1954 totalled 14,524 tons, an increase of 15½% over the previous year. The largest producer is *S.A. Cros* with two plants.

The balance of about 7,000 tons (15%) is consumed in the manufacture of SO_2, sulphites, dyes, rubber compounding, and miscellaneous uses. New projects include a rayon pulp plant and a tyre factory at Bilbao, in which the Dunlop Rubber Company is to hold a minority interest.

Sulphuric Acid

Production of sulphuric acid in 1954 totalled 778,696 tons (100% H_2SO_4), an increase of over 10% compared with output in 1953.

The following table shows the rapid development of the acid industry since 1949 :—

Production (000 tons H_2SO_4)

Year	*Contact*	*Chamber/ Tower*	*Total*	*Capacity Employed* %
1949	51·1	403·9	445·0	57
1950	60·2	446·3	506·5	64
1951	103·4	487·3	590·7	68
1952	157·9	547·0	704·9	73
1953	166·1	540·5	706·6	72
1954	193·0	586·0	779·0	77

Plant developments during 1954 accounted for an increase in acid making capacity of about 27,000 tons (100% H_2SO_4), of which 10,000 tons were new contact acid facilities. Existing plans provide an increase of about 72,000 tons per annum chamber/tower acid at seven new plants and 720,200 tons per annum contact acid at twenty-four new plants. The largest single plant project is that of the *Empresa Nacional Siderurgica S.A.* at Avilés which foresees an annual output of 194,400 tons (100% H_2SO_4). Tenders for a 400 ton per day pyrites roaster and corresponding acid converter were sought early this year.

Other large schemes are foreseen by *Sefanitro* at Luchana-Baracaldo (51,000 tons) and *Empresa Nacional Caevo Sotelo* at Puertollano (68,100 tons). These three projects, together with several smaller plants scheduled to produce some 51,000 tons acid, would supply the requirements for ammonium sulphate manufacture, which is receiving high priority. The bulk of the remaining projects are designed to supply acid for superphosphate manufacture.

It is estimated that the annual acid output is at present consumed as follows :—

	Tons
Superphosphates	470,000
Ammonium sulphate	105,000
Textiles	80,000
Metallurgy and ore treatment ...	50,000
Miscellaneous	70,000
Total ...	775,000

As acid for fertiliser manufacture accounts for about three-quarters of total usage, the proportion of captive acid is high. The largest single producer is *S.A. Cros*, who operates twelve plants with an aggregate capacity of about 330,000 tons acid or one-third of installed capacity. At the end of 1954 there were in operation fifteen contact acid plants, with an average capacity of 16,320 tons a year (100% H_2SO_4) and thirty-eight chamber/tower plants with average capacity of 19,550 tons a year. The largest single plant is that of Sefanitro at Luchana-Baracaldo, designed to produce 102,300 tons a year contact acid, mainly for ammonium sulphate manufacture.

Pyrites residues

At Badalona a plant to treat 50,000 tons per annum pyrites residues is on the point of completion. It is based on a design by Lurgi, and it is understood that a number of these are to be erected over the next few years. The large cinder extraction plant project at Luchana-Baracaldo to treat high cupreous residues remains in abeyance for the time being.

Trade and Prices

Owing its development to the pyrites needs of foreign countries, the Spanish industry's fortunes continue to fluctuate in accordance with demand principally of the U.K. and Western European acid industries. Whereas in the mid-twenties exports of Spanish pyrites met 56-60% of the European pyrites market, in two decades, disregarding the

freak conditions of war years, their share of this market fell below 40%, mainly as a result of the expansion of Portuguese and Cypriot production and exports. At the same time, this market contracted, due to the increased use of elemental sulphur in acid manufacture and the loss of East European markets, on account of political changes.

As the result of increased pyrites usage since 1950, the position to-day is slightly more favourable—Spanish pyrites account for about 41%—although the recession of consumption and imports in 1953 disclosed the vulnerability of Spanish exports, which suffered the greatest setback compared with other exporting countries. This is caused to a lesser extent by qualitative considerations, although the arsenical contamination of most Spanish pyrites is an adverse factor. The two main reasons are thought to be that, as the largest producer, Spain has always assumed the position of price leader, generally charging the highest price, and to psychological factors in that consumers confident of being able to obtain Spanish pyrites tend to fill their requirements from other sources first and call on Spain to meet the balance of their needs.

Details of exports during the past two years are as follows :—

	000 tons	
Destination	*1954*	*1953*
U.K.	300·5	276·2
W. Germany	382·2	418·6
Holland	191·4	134·6
Belgium	236·0	137·1
France	227·5	87·5
Denmark	56·9	63·3
Others	60·2	74·3
Total ...	1,454·7	1,191·6

The current export price of 105/- per metric ton is the result of applying a special exchange rate, which is at the discretion of the government. At present it is Ptas. 61·32/£1, having increased in July, 1953, from Ptas. 58·94/£1 ; these rates compare with an official rate of Ptas. 30·66 and a free rate of Ptas. 110.

The domestic price in terms of pesetas is only about 60% of the export price, and this differential, in view of the rising home consumption, tends to exert an upward pressure on export prices.

To meet the domestic demand of elemental sulphur, Spain is obliged to import up to 10,000 tons per annum. Due to U.S. dollar stringency, supplies are sought from other sources, and in recent years sulphur of Chilean, Mexican, Norwegian, and Italian origin, has been imported.

The internal price of sulphur is at present more than twice the world market price. Marketing is controlled, and the price difference is used to subsidise domestic native production.

Conclusion

The current level of production of sulphur in pyrites of about 920,000 tons per annum, although about 40% below that achieved in earlier years when pyrites were the principal source of sulphur, still enables Spain, who in 1954 delivered about 700,000 tons sulphur in pyrites to foreign markets, to hold its position as the largest pyrites exporter in the world. The production of elemental sulphur from pyrites by the Orkla process, limited by available plant capacity, was to have been expanded considerably by the Rio Tinto Co., Ltd., by the installation of additional furnaces, but it is uncertain whether this project will be pursued by the new management, as the imminent start of a 30,000 ton per annum plant for the recovery of sulphur from roaster and smelter gases by Cia Real Asturiana will meet foreseeable needs.

Notwithstanding the potential sources of elemental sulphur supply, such as the better utilisation of native ores and the possible use of sulphur in refinery gases of the Spanish oil industry, the essential interest, both of the expanding domestic sulphuric acid industry and of an appreciable section of the acid industries of the West European countries, is focused on the future of Spanish pyrites.

Although to a lesser extent than in the past, the present-day developments of the Spanish sulphur industry are influenced by its ability to command as large a share as possible of the market of sulphur importing countries. Whereas up to five years ago the home market rarely absorbed more than 10% of the country's output of sulphur in its various forms, to-day its needs account for more than one-third, and the existing expansion plans of the sulphuric acid/fertiliser industry point to domestic demand accounting for an increasingly greater propor-

tion of production. In view of the importance of pyrites to the Spanish balance of payment position, consumption, unaccompanied by increased production permitting at least the maintenance of the present level of exports, is unlikely to be acceptable to the Spanish government. The future of pyrites, and that of the Spanish industry in particular, rests between the apparent greater security of pyrites supplies and the adverse trend of the cost of sulphur in pyrites compared with that of elemental sulphur. In the light of available Frasch sulphur supplies and in view of the increasing use, throughout the world, of indigenous sulphurous raw materials, the refining and recovery of which is made economical by technical advances, it is thought that only the competitive supply of sulphur in pyrites would ensure their being able to maintain a significant share of the total market. Because of the uncertainty whether, under prevailing conditions, the producers of Spanish crude pyrites will succeed in this, the developments in dissociating economically sulphur and metal values in pyrites are of special importance to the Spanish pyrites industry.

Yugoslavia

General

Although there are no native sulphur deposits in Yugoslavia, nor is there any immediate prospect of by-product elemental sulphur production, the country has large resources of sulphur in other forms.

At present the sulphur industry is based almost exclusively on pyrites which occur primarily in conjunction with non-ferrous metal sulphides. The large-scale non-ferrous smelting operations provide an important potential source of sulphur supply and there are also extensive anhydrite deposits along the Adriatic coast which are about to be exploited in conjunction with a major acid plant project.

The pyrites industry was established on a commercial basis in 1908, but it only assumed significant proportions in the 'thirties when British and French companies who had developed large-scale lead, zinc and copper enterprises started producing pyrites concentrates as part of their ore flotation operations. Although the home market remained underdeveloped, pyrites production expanded rapidly and under the stimulus of exports to Central and Western European sulphuric acid makers, which provided a valuable source of additional revenue to the mining companies, production by 1938 rose to over 150,000 tons pyrites.

The dependence of the industry on exports still holds good to-day although the emphasis on increased industrial activity in the nationalised Yugoslav economy after the war resulted not only in rapid progress in the reconstruction of war-damaged chemical works—by 1946, most of them were again in commission—but also in substantial plans for increased sulphuric acid output. The index of chemical production rose from 100 in 1939 to 177 in 1953 and was planned at 220 in 1954. Although the expansion of acid output was substantially greater—having increased more than fourfold since 1939—it is nevertheless still inadequate to meet the growing requirements of the country's increasing number of industrial users.

The demands of the fertiliser industry are particularly pressing, as the government is anxious to raise agricultural output, whilst installed fertiliser capacity, which itself is inadequate, still exceeds available acid-making facilities. At the same time, the potential output of sulphur exceeds ½-million tons annually, wheras actual production in 1954 was only about 85,000 tons due to the shortage of domestic pyrites roasting facilities, the limitation of export markets for pyrites and the lack of recovery facilities for sulphur in smelter gases. Total consumption of sulphur in all forms is at present only about 27,000 tons a year, of which 85% is in the form of pyrites, 5% taken from smelter gases for sulphuric acid manufacture, and the balance imported elemental sulphur. There are ambitious plans to use the great sulphur potential and to raise domestic consumption, primarily by the installation of new acid/fertiliser plants. The country's economic means for capital investment only points to a more modest, though steady, growth, but with foreign aid in the form of loans by the U.S.A. and the recently announced agreement for technical co-operation with the U.S.S.R. these plans are likely to be realised more rapidly.

Pyrites Deposits and Production

At present, pyrites output is almost exclusively in the form of concentrates resulting from differential flotation of non-ferrous metal sulphide ores. The production of crude pyrites, which had reached over 50,000 tons a year and generally accounted for at least one-third of total output, started to decline about 1946, since when these ores, containing copper values up to 2%, have been diverted increasingly to copper production. Total pyrites production is at present about 160,000-170,000 tons annually of which less than 2% is crude ore. Potential output is more than double this figure, but the limitation of relatively low domestic consumption and fluctuating export markets do not permit the greater use of the pyrites tailings which arise in the course of non-ferrous ore treatment.

The following graph shows the trend of pyrites production between 1946 and 1954 :

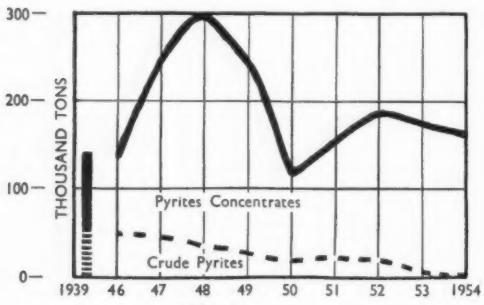


Fig. 3

The bulk of Yugoslavia's pyrites output originates from three sources.

Trepca. This group of lead/zinc mines, exploited in Roman times and in the Middle Ages by Saxon miners, was rediscovered by engineers of the Selection Trust, Ltd., in 1925. Production, centred on the largest deposit, Stantrg, started in 1930 and rapidly expanded to 600,000-700,000 tons per annum ore containing 8-9% lead, 3-4% zinc. The deposit is massive comprising galena, ferrugenous blende, pyrite and pyrrhotite. The two last named account for the majority of the ore body, their proportion increasing in depth, so that below the 435 metre level, i.e. some 1,200 feet below the top workings, there is practically massive pyrrhotite with disseminated galena. Fully proved reserves in 1940 totalled five million tons ore, with probable reserves many times greater. Currently development is reported to be carried down to the 315 metre level.

Production of pyrites concentrates started in 1933 and reached a peak level of about 100,000

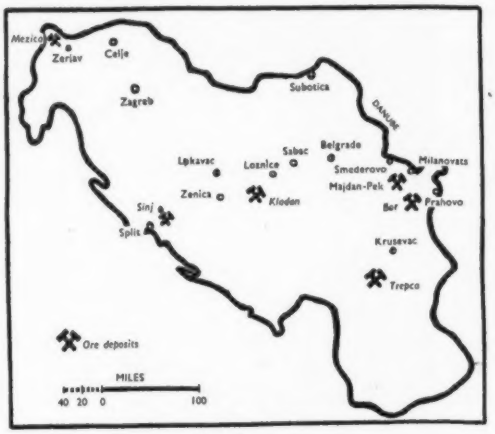


Fig. 4

tons in 1937/8 when it accounted for more than two-thirds of total Yugoslav output. Current annual output is believed to be about 80,000 tons of pyrites concentrates containing 47-49% sulphur. The flotation plant, at present capable of treating 1,800 tons ore daily, is scheduled for enlargement, with the object of raising the output of lead concentrate. Under British management Trepca was the lowest-cost producer of lead in the world and in spite of present shortages of materials and experienced technicians operations are still favourable. Among similar deposits in the district Kapaonik and Novo Brdo are the largest though neither is as yet being worked.

Bor. The largest copper mine in Europe, the Bor deposits were developed by French capital. Consisting of three large lenticular masses in andesite lavas, each about 150 metres long, 80 metres wide, and explored to a depth of 220 metres, they contain high grade copper ores. From the start of mining operations in 1910 until 1933 the bulk of copper production resulted from direct smelting of ore containing 9% and more copper. The decrease in copper values as exploration reached greater depth led to the installation in 1933 of a 300 tons per day ore-flotation plant which in 1938 was expanded to 2,000 tons per day when large-scale by-product pyrites production also started.

Thanks to a Krupp installation delivered as part of German reparations and a Denver plant delivered under U.N.R.R.A. the ore treatment plant was modernised after the war, and its capacity raised to 2,600 tons per day. Currently Bor produces annually about 80,000-100,000 tons pyrite concentrates containing 45-46%S, although plant capacity would permit at least double this output.

Majdan-Pek. This deposit was the first major source of pyrites to be exploited in Yugoslavia. A large massive deposit several hundred metres long, it contains primarily chalcopyrites. Up to 1946 the bulk of its output of up to 50,000 tons annually containing 46-47% sulphur and up to 2% copper was sold as crude pyrites. At present practically the entire output from the old mine and that of the new sections recently developed, and found to contain about 100 million tons of copper sulphide ore in three levels, is diverted to copper production, the ore being transported to Bor for treatment.

An important new pyrites deposit was discovered in the Kladan district last September by a team of Yugoslav geologists. Due to the great mineral wealth of the country, further discoveries of important sulphide ore bodies are likely although in view of the unused pyrites capacity by existing producers their development will depend primarily on their yield of non-ferrous metal.

Smelter Gases

At present there is only one non-ferrous ore smelter where use is made of the sulphur content of the roaster gases. It is the 30-ton per day smelter of the Cinkarna Company established at Celje in Slovenia by the Austrian Government before the first world war to treat zinc concentrates from the Raibl and Bleiberg mines. The by-product acid plant, believed to have an annual capacity of 4,000-5,000 tons (100% H_2SO_4), converts the sulphur dioxide content of the gases by the chamber process.

None of the other smelters such as the lead smelters at Zerjav, treating Mezica concentrates, and at Trepca, nor the copper smelter at Bor have the facilities to use the sulphur contained in exit gases. Particularly at Bor, due to the large volume and high SO_2 content of blast furnace (2%) and converter (8%) gases, air pollution has caused great damage to crops and vegetation in the surrounding district for many years. Partly for this reason, but primarily to increase domestic acid supplies, the Yugoslav Government has incorporated, in the modernisation plans for the Bor smelter, provision for a by-product acid plant with an initial capacity of $\frac{1}{4}$-million tons (100% H_2SO_4). The output is to be carried by pipeline to Prahovo on the Danube, 40 kms. distant, where a superphosphate plant with an annual capacity of 694,000 tons is to be erected. This may later be expanded to produce 1·4 million tons. Although in 1954 £5 million (in local currency) was assigned for the main project and a further £30 million earmarked for subsequent investment, lack of foreign currency required for essential equipment may postpone the realisation of the complete project for several years.

Consumption

Total consumption of sulphur in all forms is now about 27,000 tons annually, having increased progressively from about 7,000 tons in 1939. Of this tonnage 3,000-4,000 tons annually is imported in the form of elemental sulphur and is used mostly in agriculture, also increasingly for rubber vulcanisation, the manufacture of sulphur dioxide, sulphites and other chemical products. No elemental sulphur is used in the manufacture of sulphuric acid which is made wholly from pyrites and as a by-product from smelter gases which account for the balance of sulphur consumption.

Immediate expansion plans of the sulphuric acid industry, in the form of projects in hand, indicate that by the end of 1956 consumption may increase by some 50,000 tons sulphur. Sulphur usage by non-acid industries is expected to increase substantially from 1957 onwards when a viscose rayon and transparent paper plant is due to start operating. Final plans for this plant, which is to be built by two Japanese companies, the Mitubishi Engineering and the Shibaura Electric at a cost of U.S.$12 million were approved in July. It is to be erected at Loznice and will have an annual capacity of 20,000 tons rayon filament staple, tyre yarn and film which will entail the use of about 4,000 tons sulphur in CS_2 and about 8,000 tons sulphur in sulphuric acid.

Sulphuric Acid

Production of sulphuric acid* in 1954 totalled about 60,000 metric tons (100% H_2SO_4), half as much again as in 1953. Except for about

*For details, see Statistical Appendix.

4,000 tons of by-product acid from zinc smelter gases the entire output resulted from the roasting of indigenous pyrites concentrates.

The principal producer of acid is Zorka, a large metallurgical and chemical combine, which produces nearly three-quarters of the country's output at its Sabac works. The bulk of the output is captive and is mainly used in the manufacture of superphosphate and copper sulphate.

Plant capacity at Sabac is currently being raised by 50,000 tons (100% H_2SO_4) to 93,000 tons by the addition of new pyrites roasting furnaces and by extension of SO_2 conversion facilities, probably in the form of new contact units.

Most of the remaining acid output originates from Merima, a chemical works at Krusevac, and the by-product acid plant of Cinkarna, the zinc smelter at Celje. These two works are scheduled to deliver all their output in 1955 to the coke oven works at Lukavac and Zenica, where manufacture of by-product ammonium sulphate was due to start.

It is estimated that the present acid output falls short of the minimum requirement of the Yugoslav economy by at least 50,000 tons. The largest single factor is the requirement of the superphosphate plant of Zorka at Subotica which has an annual consumption capacity of 27,000 tons (100% H_2SO_4) and which at present relies entirely on imported acid. As total acid imports in 1954 were only about 5,000 tons, its contribution to Yugoslav fertiliser needs is at present negligible. To remedy this the construction of a 50,000 t.p.a. acid plant at Subotica is under consideration.

The principal expansion project, reported to have been put in hand, is a plant for the production of sulphuric acid and cement from gypsum. This is being erected at Sinj, north of Split, where extensive reserves of the mineral are found. The total projected capacity of the plant is 90,000 tons a year.

Superphosphate and Other Uses

The principal use of sulphuric acid is in the manufacture of superphosphates. Production in 1954 totalled 120,600 metric tons (16% P_2O_5) which originated mainly from the Sabac works of Zorka, where plant capacity has been increased to 120,000 tons towards an annual target of ¼-million tons superphosphate.

The country's present minimum requirements are estimated to be 300,000 tons superphosphate, part of the deficit being made up by imports.

The manufacture of coppersulphate, of which 13,000-15,000 tons are produced annually, take a substantial share of the remaining acid supplies for which competing claims originate from makers of ammonium sulphate, aluminium sulphate, the steel industry and a large number of various small consumers.

Trade

The ability of the Yugoslav pyrites industry to dispose of a large proportion of its output in foreign countries still determines its level of activities. In 1954 exports amounted to 131,000 tons, representing three-quarters of the total pyrites output and valued at the equivalent of £3 15s. per ton pyrites.

Apart from ordinary sales which yield a substantial foreign exchange revenue, pyrites were prominent in barter transactions after Yugoslavia left the Cominform in 1948 and ceased to trade overtly with the Iron Curtain countries. These exchanges were made through a "neutral" country, usually Switzerland, or Austria, in exchange for coal and metallurgical coke. For some years, Germany has been the largest importer of Yugoslav pyrites concentrates and received 86,000 tons last year*.

Low cost shipping facilities on the Danube make Central European countries the natural outlet for Yugoslav pyrites, and the Danube ports of Smederovo, Prahovo, and Milanovats, the former accessible by rail from Trepca and Bor respectively, the last named linked to Majdan-Pek by aerial ropeway, are well equipped for ore handling. Exports to Western Europe generally move through Salonika or North Adriatic ports.

The lack of indigenous elemental sulphur supplies necessitates the import of the country's requirements, which in recent years have totalled up to 5,000 tons a year. The natural source of supply is nearby Sicily, but the sorry state of its industry and the exorbitant prices have forced Yugoslavia to import sulphur from the U.S.A. albeit with aid dollars. Other supplies, notably refined grades, have been imported from Western Germany.

*—For full details see Statistical Appendix.

To alleviate the shortage of acid, several thousand tons a year are imported from Austria, Hungary and Italy. The fact that despite the prevailing domestic shortage Yugoslavia has in recent years increased its acid exports—directed wholly to Austria—to over 1,000 t.p.a. may be explained by the greater liberty of action enjoyed by individual enterprises in the profitable disposal of their products.

Conclusion

Whereas much of Yugoslavia's future industrial development is influenced by the achievement of the non-ferrous metal industry —the country's main source of foreign revenue —the sulphur industry is wholly dependent on the scope of its activities. In view of the expansion of non-ferrous ore mining and refining activities, the prospects of availability of increasing quantities of low cost by-product pyrites and of the use of sulphur in smelter gases are promising. Although there is no immediate indication of elemental sulphur production, its recovery from smelter gases is feasible.

The recent improvement of political relations with the U.S.S.R. and the East European satellite countries will undoubtedly be reflected in greater pyrites exports, which, as far as markets such as Austria and Western Germany are concerned, may also benefit by the improvement of transport facilities on the Danube. Under the agreement on technical co-operation with the U.S.S.R., announced on 1st September, Yugoslavia is to receive credit to pay for various planned industrial projects including acid and fertiliser plants. As the planned expansion of domestic plant facilities is largely dependent on foreign exchange resources—for which there are many competing claims by other, notably the heavy, industries—and is also limited by the availability of experienced technicians it would, without outside help, be unlikely to show quick results.

One of the most interesting features in the Yugoslav economy is the combination of Socialist state planning with certain aspects of free enterprise normally associated with Capitalist economies. The effect of this policy on the sulphur industry by virtue of the activities of individual mining and chemical enterprises in trading, plant development and labour relations could, if successful, accelerate its rate of expansion.

Prices and Trends

DURING the past three months the world price, as represented by the price of American sulphur, has remained substantially unchanged. The upper limit of $33, previously established by a number of exporters of bright sulphur, appears to have been abandoned; indeed, a small number of sales of this grade are reported to have been effected at prices below $31, the level established in January, 1954, by the two principal producers, Texas Gulf and Freeport Sulphur Companies. Under the impact of lower Mexican prices there has been some pressure on U.S. producers to reduce the existing differential between domestic and export prices, although there are no indications as yet that such a change is imminent.

The price of Mexican sulphur, notably in European markets, appears to have settled at a level of $26·50-$28 per ton f.o.b. In view of the limited volume of sales in relation to producers' output, their attention, as was expected, has turned in recent months to the U.S. domestic market where they are reported to have secured a number of important contracts at competitive prices.

In Italy there has been a slight reduction of the official export quotations by the Ente Zolfi Italiani, which bring the price of Gialla Superiore (min. 99·5% sulphur) to Lire 27,000 per metric ton (£15.14s. per ton). A further reduction aimed at stimulating export sales is reported to be under consideration although, if it is to make Italian sulphur competitive with bright U.S. sulphur, it will have to be at least Lire 5,000-6,000 per metric ton.

With the aid of proceeds from compensating commodity imports the effective price of Chilean sulphur ranges from $24 per metric ton f.o.b. to under $20. The bulk of available export supplies are committed, under existing sales arrangements, mostly to Western European and Scandinavian destinations.

The following table shows a comparison of sulphur of different origin. F.o.b. prices and freights are based on recent quotations :—

	f.o.b. Country of origin	*to U.K. Freight**	*per ton c.i.f. U.K.*
U.S.A.	U.S.$29.50 - $31	97/6	£15½ - £16
Mexico	U.S.$26.50 - $28	97/6	£14⅛ - £14⅞
Italy/Sicily	L.27000	64/-	£18⅞
Chile	$18 - 24	110/-	£12 - £14½
Japan	U.S.$34†	112/-	£17⅞
Ecuador	U.S.$42	115/-	£20¾
Canada	$20 ex works	112/-	£19½

Prices of European pyrites are stable at £4 15s. to £5 5s. per metric ton f.o.b. In view of the increasing pressure of domestic pyrites residues on treatment facilities in West Germany these plants, already with more than one year's stocks in hand, are finding it increasingly difficult to maintain their offtake of residues from roasters in neighbouring countries Whereas the value of residues has taken a further upward turn, a lesser volume of pyrites is reported to enjoy the benefit of the improved returns.

The continued demand for tramp shipping space, notably by the North Atlantic coal trade, has resulted in a steady increase of sulphur and pyrites freights rates. Over the past three months rates from the Gulf of Mexico to U.K. and Western Europe have risen by about 20% and pyrites freight from Spain, Portugal and Cyprus to similar destinations by about 15%.

The restriction on output by U.S. producers, which has been apparent since early this year, has not caused any repercussions on supplies. The heavy domestic demand in the spring followed by above average demand during the summer months and accompanied by substantial export sales was easily met and the resultant reduction of stocks appears to accord with producers' policy. U.S. producers continue to seek further export business, and although meeting strong competition from Mexican producers do not so far appear to have suffered any significant losses of markets.

Mexican export supplies are gradually establishing themselves in world markets as the result of earlier trial shipments having generally proved satisfactory. Shipments of Mexican sulphur to the U.S.A. are expected to start shortly with the result that the end-of-year stocks may not be excessive. Although a third producer, Gulf Sulphur Corporation, is due to start producing in October supplies from this source are unlikely to reach markets before the start of the New Year.

In Italy the successful completion of trials at Perticara of Montecatini's new refining plant, which is based on the Masobello process, marks an important step towards introducing economic production methods. In recent months, in spite of a number of export deliveries, a substantial proportion of the output remained unsold and it is believed that the stockpile now appreciably exceeds 330,000 tons, which is the limit on which the government subsidy is payable.

In Japan a six-week strike which brought all non-ferrous metal mines to a standstill was settled on 17th June, after wage increases were agreed. It is estimated that the loss of ore output will result in a 10-15% reduction of this year's pyrites supplies and a cut of about 10% in refined sulphur production. This may affect Japan's ability to meet in full both the export commitments of about 10,000 tons to Australia and her rising domestic demand.

Production in Chile is unable to keep pace with domestic requirements and export demand which was expected to total about 80,000 tons for the current year. Bad weather and exceptional cold in the high regions where the mines are situated has cut production by as much as 50% since April and it is now considered unlikely that, in addition to some 25,000 tons needed by the home market, Chile will be able to supply as much as 50,000 tons for export. To date the principal receivers of Chilean supplies are France, West Germany, Finland and Sweden, exports during the first half of 1955 having totalled 29,025 metric tons.

European pyrites demand is reported to have eased in recent months, mainly under seasonal influences. The use of indigenous sulphur resources in various forms is increasing. Anhydrite in the U.K. and Turkey, natural and oil refinery gases in France are notable examples.

World requirements of elemental sulphur, which are increasing at a more rapid rate than hitherto in view of renewed construction activity of sulphur-burning acid plants and greater "regular" usage, are being met comfortably. The present highly competitive supply position is expected to remain unchanged.

*—Based on bulk cargoes of 5,000-6,000 tons on the usual sulphur terms of chartering.
†—Calculated on basis of sales to Australia.

UNITED STATES SULPHUR

Native Sulphur

DURING the second quarter of 1955 production of Frasch sulphur amounted to 1,318,296 tons and, although 37,000 tons (3%) greater than during the preceding quarter, output was 3½% lower than during the corresponding period of 1954.

Apparent sales were the highest on record and the total of 1,533,806 tons was 115,000 tons (8%) higher than during the preceding quarter and 9½% greater than during the second quarter 1954. The high rate of sales—about 6½ million tons per annum—reached in March was maintained until May, and consumption in June, although lower than in the preceding months, still exceeded that of June, 1954, by about 10%.

Production of sulphuric acid totalled over 3·9 million short tons—13½% more than during the second quarter 1954—as the result of sustained demand from the steel, rayon, petroleum and detergent industries. Requirements for fertiliser manufacture eased considerably during the quarter, partly due to an earlier falling off of superphosphate and ammonium sulphate disposals partly as the result of prolonged strikes affecting a large section of the superphosphate industry in the south.

The high level of consumption by non-acid users was maintained, rayon, pulp and rubber manufacture exerting the strongest pressure on supplies. Exports showing a strong seasonal advance amounted to 419,884 tons in the second quarter, and the total of 759,160 tons exported during the first half-year exceeded that of the corresponding period in 1954 by about 10,000 tons.

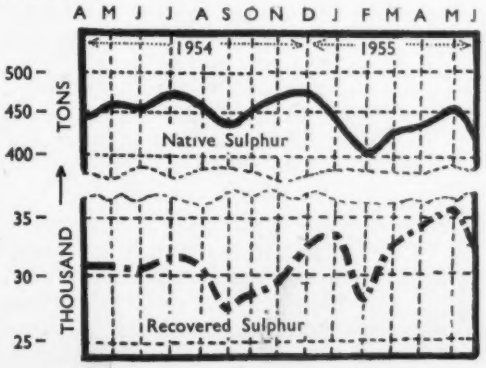


Fig. 5
Monthly Production Figures

In view of the relatively low level of output and high demand, stocks receded 215,510 tons (7%) to 2,875,387 tons at the end of June, the lowest total since the first quarter 1952.

Recovered Sulphur

Production of sulphur recovered from natural and oil refinery gases amounted to 102,000 tons, the highest quarterly total on record. Output was 8,600 tons (9%) higher than in the preceding quarter, which had hitherto been the highest, and was 9,500 tons (11½%) greater than that of the second quarter 1954.

Apparent sales totalled 102,643 tons and, showing the usual seasonal increase, were 5% higher than in the second quarter of last year. Stocks showed little change and totalled 123,266 tons at the end of June.

Summary—Second Quarter 1955

(a) As the result of the continued low level of production of Frasch sulphur during the second quarter, output of native and recovered sulphur in the first half-year amounted to only 2,795,246 tons, 4½% less than during the corresponding period of 1954. It represents an annual rate of about 280,000 tons less than that achieved in 1954, notwithstanding the increased recovered sulphur output which now arises at a rate exceeding 400,000 tons per annum.

(b) The continued high level of domestic consumption and the seasonal increase of exports resulted in apparent sales of native and recovered sulphur during the first half-year of 3,133,679 tons. This tonnage, the highest on record, is about 410,000 tons (15%) greater than that of the corresponding period of 1954.

(c) Stocks of native and recovered sulphur at the end of June totalled 2,998,653 tons, a reduction of 330,000 tons since June, 1954, which brought stocks down to the general level of the first quarter of 1952. It is not thought likely that this rate of depletion of surface stocks of Frasch sulphur will be maintained, particularly since domestic consumption during the first half-year exceeded producers' expectations. The timing and the extent of imports of Mexican sulphur will no doubt play a part in influencing their decision as to the level at which it is expedient to maintain U.S. Frasch sulphur stocks.

Sulphur in O.E.E.C. Countries

THE sulphurous materials situation in 1954 in the member countries of O.E.E.C. is reviewed in the draft report recently published by the *Chemical Products Committee*. In the absence of details of the Turkish sulphur industry—a regrettable omission in view of its notable developments in the past five years—their summaries of the period under review and the comparison with earlier years are restricted to the other fourteen member countries.

Native and Recovered Sulphur

Production of elemental sulphur in 1954 totalled 476,000 tons*, of which about 43½% resulted from the refining of native ores in Italy and Greece. Sulphur recovery from industrial gases and pyrites (Orkla) totalled 270,100 tons, an increase of 66% over the tonnage so produced in 1949/50, whereas native sulphur production decreased about 10% during the same period. Figure 6 indicates the fluctuation of the elemental sulphur deficit in O.E.E.C. member countries.

The contraction to little more than one-half of sulphur exports is wholly due to the inability of the Italian output to sell at competitive prices. Of the 1954 export total of 145,000 tons only 73,000 tons were shipped to non-member countries.

Elemental sulphur consumption in 1954 rose to 946,700 tons, i.e. within 5½% of the peak level reached in 1949/50. Since 1951, when the effects of restriction on sulphur burning in sulphuric acid manufacture first became apparent, there has been little change in the pattern of consumption, which was as follows :—

	1949-50 %	*1951* %	*1952* %	*1953* %	*1954* %
Sulphuric acid ...	47.5	36.6	37.0	38.0	36.6
SO_2	11.6	14.9	14.3	15.9	14.3
CS_2	19.1	24.9	21.2	26.9	25.5
Agriculture ...	12.5	13.3	16.8	10.6	13.2
Other uses ...	9.3	10.3	10.7	8.6	10.4
Total sulphur (thousand metric tons)	1,003	996.3	735	800.9	946.7

Although the net sulphur deficit in 1954 of 543,100 tons masks both the additions to the Italian stockpile of about 90,000 tons and the excess of about 20,000 tons in shipments over production by Norway, net imports from outside sources of supply appear to have permitted an aggregate increase in consumer stocks of about 95,000 tons during the year. Total imports in 1954 of 799,800 tons, of which 89·5% are said to have originated in the U.S.A., were the highest for four years and only 1¼% below the 1949/50 peak.

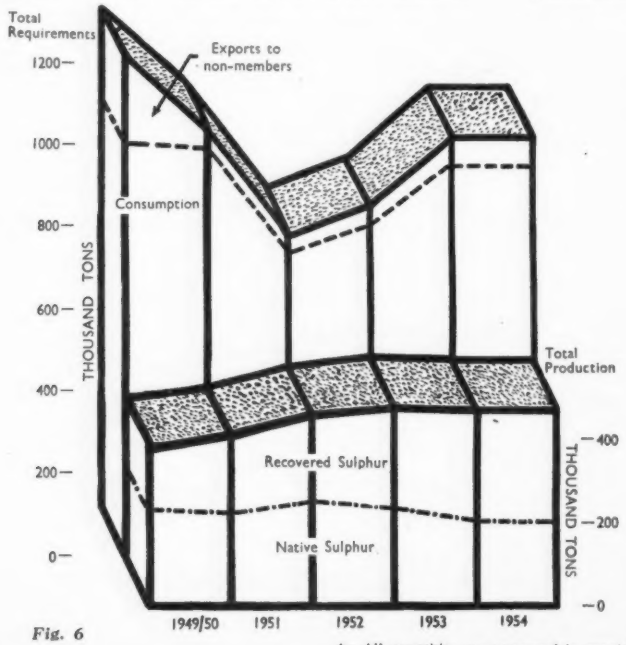


Fig. 6

Pyrites

Production in 1954 totalled 1,682,000 tons sulphur in pyrites, the modest increase (¼%) compared with 1953, the previous post-war peak year, being occasioned by the greater output in Germany and Norway which offset the reduction in Portuguese output resulting from Government restrictions.

As the result of substantially increased imports from outside sources, principally Spain, totalling 785,000 tons sulphur in pyrites, and increased shipments from Cyprus, a further small

*—All quantities are expressed in metric tons.

addition to consumer stocks, totalling about 60,000 tons, appears to have been effected, notwithstanding the high level of consumption which, amounting to 2,743,000 tons sulphur in pyrites, was 13½% greater than in 1953 and 37% greater than in 1949/50. By comparison the decerase in acid sulphur consumption during the same period was about 27%, with the result that the proportion of sulphur in pyrites to elemental sulphur used in acid manufacture rose from about 4:1 to 8:1.

Zinc Blende

Production of zinc blende, which had remained stable in the previous four years, increased about 12% in 1954 to 141,700 tons sulphur in blende, mainly on account of increased output in Sweden and Italy. Consumption of 410,000 tons sulphur in blende was 9% higher than in 1953 and 31% more than in 1949/50. Supplies from non-member countries of 163,600 tons, accounting for 53% of total imports, supplemented imports from member countries and their overseas territories although discrepancies in the latter figures do not permit an assessment of the overall position.

Sulphur in Other Forms

Production and consumption of other sulphurous raw materials, of which anhydrite accounts for about 56% of the total, spent oxide (36%) and mine wastes (8%), totalled 588,300 tons sulphur, 60% more than in 1949/50. Available supplies in 1954 which, with the exception of about 30,000-40,000 tons sulphur in spent oxide exported from the U.K. to the Continent, are consumed in the country of origin, slightly exceeded requirements.

Summary

The production of all sulphurous raw materials in O.E.E.C. countries increased 25% since 1949/50, to 2,888,600 tons in 1954, but now appears to be static at this level. Consumption on the other hand, which increased 27% in the same period to 4,671,600 tons, showed a further increase of 12% compared with 1953.

The easy supply position, notably in elemental sulphur, has permitted an increase in consumer stocks of about 150,000 tons sulphur in various forms not including the addition to the stockpile of Italian native sulphur. Moreover, compared with 1953, the rate of increase of elemental sulphur consumption (18%) was greater than that for sulphur in pyrites (13%).

	PRODUCTION*					CONSUMPTION*				
	1949 1950	1953	1954	Change % (a)	Change % (b)	1949 1950	1953	1954	Change % (a)	Change % (b)
Native Sulphur	231.6	245.4	216.5	−6½	−12	—	—	—	—	—
Recovered Sulphur	163.0	243.4	270.1	+16½	+11	—	—	—	—	—
Elemental Sulphur	394 6	488.8	486.6	+ 23	− ½	1010.3	810.7	956.9	− 5	+ 18
Pyrites	1430.0	1688.1	1693.0	+ 18½	+ ½	1996.6	2429.6	2754.3	+ 38	+ 13½
Zinc Blende	127.5	127.6	141.7	+ 11	+ 11	312.5	375.5	410.2	+ 31	+ 9½
Others	368.5	580.9	588.3	+ 60	+ 1½	377.0	562.7	571.4	+ 51½	+ 1½
Total	**2320.6**	**2885.4**	**2909.6**	**+ 25½**	**+ 1**	**3696.4**	**4178.5**	**4692.8**	**+ 27**	**+ 12½**

* *Thousand Metric Tons Sulphur Content.*

Including details of production and consumption in Turkey.

(a) *Increase/Decrease compared with 1949/50.*

(b) *Increase/Decrease compared with 1953.*

UNITED KINGDOM SULPHUR

DURING the second quarter 1955 consumption of sulphur in all forms,* amounting to about 214,000 tons, was 4% lower than in the preceding quarter, but exceeded consumption during the corresponding period of 1954 by 2½%. The overall reduction in consumption was in line with seasonal trends. The decline of regular sulphur usage was greater than the level of activities of the principal users, notably rayon manufacture, would warrant. The sizeable drop of 12½% in acid sulphur usage was partly due to the increasing availability of anhydrite acid, notably at the Billingham plant of I.C.I., where the use of acid sulphur is believed to have been substantially curtailed. Pyrites usage, 3½% lower, was similarly affected, but as yet to a lesser extent. The start of operation in May of the anhydrite acid plant of United Sulphuric Acid Ltd., at Widnes, further increased the use of this raw material, which is now being consumed at nearly twice the rate compared with one year ago.

Consumption of the various raw materials was as follows :—

	2nd Qr. 1955	*1st Qr. 1955*	*Change† %*	*2nd Qr. 1954*	*Change† %*
Sulphur					
Acid	63,300	72,500	− 12½	63,700	− ½
Regular	26,100	28,500	− 8½	27,400	− 4½
Total	89,400	101,000	− 11½	91,100	− 2
Pyrites	120,400	124,600	− 3½	124,000	− 3
Spent oxide	69,400	69,700	− ½	71,700	− 3½
Zinc concentrates	54,200	48,900	+11	54,000	+ ½
Anhydrite	82,500	66,100	+25	43,900	+88

†—Percentage figures shown indicate change between earlier periods and the 2nd quarter 1955.

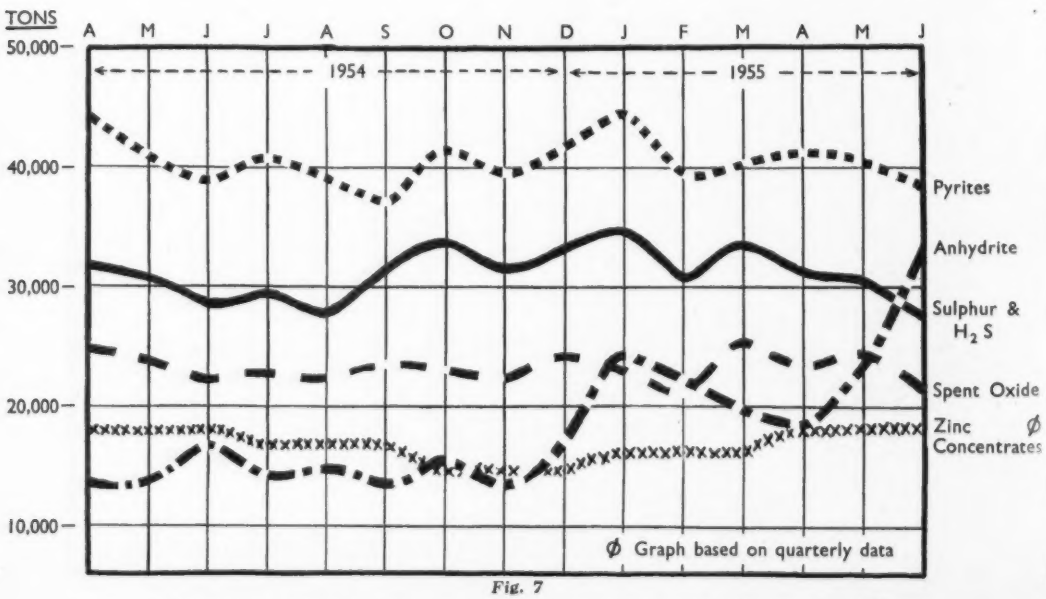


Fig. 7

*—Not including sulphur in anhydrite used in direct manufacture of ammonium sulphate which is expected to total 211,000 tons in 1955.

It is estimated that 37½% of the above total consumption was met from indigenous sources (sulphur in spent oxide, anhydrite, zinc smelter gases and recovered from coal and oil refinery gases), 27% in the form of imported pyrites, and 35½% in the form of imported brimstone. Actual imports amounted to 80,982 tons brimstone (valued at £14/19/- per ton) and 141,637 tons pyrites (valued at £7/10/- per ton).

Sulphuric Acid*

Production of sulphuric acid during the second quarter amounted to 521,900 tons (100% H_2SO_4), 2¾% less than during the preceding quarter. Compared with the corresponding period of 1954, output was 2% greater, and the same rate of increase applied to the tonnage produced during the first half-year, which was at an annual rate of 2.12 million tons.

Acid production resulted from the use of the following raw materials :—

	2nd Qr. 1955 %	*1st Qr. 1955* %	*2nd Qr. 1954* %
Sulphur & H_2S	33¼	37¼	35
Sulphur in :			
Pyrites	30¾	30½	32
Spent oxide	17¾	17¼	19
Zinc concentrates ...	8½	7¾	9
Anhydrite	9¼	7¼	5

During the second quarter of 1955 effective production capacity rose 2½% to an annual rate of 2.55 million tons, of which 81.8% was employed. The further increase is primarily attributable to the start of operations in May of the anhydrite acid plant of United Sulphuric Acid Ltd., at Widnes. Contact acid production of 368,600 tons accounted for 70¾% of total output.

Employment of sulphur burning capacity receded to about 76% and that of pyrites roasters to about 80%, while acid production from zinc smelter gases substantially exceeded rated capacity.

Consumption of sulphuric acid amounted to 522,600 tons (100% H_2SO_4), and although 5% lower than during the preceding quarter it exceeded the tonnage of acid used by British industry during the same period of 1954 by 3½%.

Acid usage by the main consumer groups was approximately as follows :—

	000 tons	%
Fertilisers	187	35.8
Chemicals (estimated)	67	12.8
Titanium & Lithopone	61	11.7
Rayon & Transparent paper	66	12.6
Iron & Steel	29	5.5
Oil Refining	15	2.9
Dyes	20	3.8
Miscellaneous	78	14.9
	523	100.0

The principal changes in individual consuming industries compared with the corresponding period in 1954 were as follows :—

	Change *Tons*	%
Rayon & Transparent paper ...	+8,500	+15
Superphosphate	+7,200	+ 6½
Sulphate of ammonia	−5,100	− 7
Titanium oxide	+4,800	+ 9
Iron & Steel	+2,600	+10
Drugs & Fine Chemicals ...	−2,500	−36

Quantitively smaller but nevertheless significant changes occurred in acid use for chromates (+61%), bromine (−53%), plastics (+20%). The decline of acid use in bromine production is believed to be temporary and occasioned by reconstruction work at one of the major plants.

Raw Material Stocks

During the second quarter of 1955 stocks of brimstone increased slightly (1½%) to 82,000 tons, which at current rate of consumption represent nearly 12 weeks supply. Stocks of pyrites increased by 11,300 tons (6½%) to 191,500, whereas spent oxide stocks further decreased 11,400 tons (8½%) to 124,800 tons, representing about 21 weeks and 23 weeks consumption respectively.

The most significant features of developments in the sulphur industry during the second quarter are :—

(a) The further increase of anhydrite use in sulphuric acid manufacture as the result of production starting at the new plant of United Sulphuric Acid Ltd., at Widnes.

(b) The relatively heavy decline (12½%) in acid sulphur usage compared with the preceding quarter.

*—We are indebted to the National Sulphuric Acid Association for information placed at our disposal.

(c) The steps taken by the National Sulphuric Acid Association for the internal distribution of imported sulphurous raw materials, which were effective in reducing the impact of the prolonged rail and dock strikes, with the result that the reduction in total acid output did not exceed the usual seasonal proportion.

During the third quarter, the anhydrite acid plant of Solway Chemicals started operations at half capacity, and competitive supplies are reaching the market, although still in relatively small quantities. When full capacity is reached later this year, an outlet for about 60,000 tons per annum acid is likely to be required within a radius of about 100-150 miles from Whitehaven, Cumberland. The effect initially is likely to be greater on elemental sulphur usage, since a proportionally larger volumne of pyrites acid is captive, and because the operation of pyrites roasters, substantially below capacity, shows grave economic disadvantages. Whereas the impact of a large volume of anhydrite acid is likely to result in an unsettled market, with attendant fluctuations in the use of brimstone and pyrites for the manufacture of "sales" acid, the natural increase of acid requirements can be expected to mitigate these effects after the end of next year. Plans for new plant projects which are likely to be realised by the end of 1956 point to renewed increase of brimstone use. This will then receive an additional impetus by the removal of government controls of import and consumption quotas, which are expected to be rescinded at the end of this year, without, however, having an immediate effect.

Sulphur in Mexico

OUTPUT of Frasch sulphur by the two active producers, Pan American Sulphur Company at Jaltipan and Mexican Gulf Sulphur Company at San Cristobal has been maintained in recent months at a daily rate of about 1,800-1,900 tons.

At Jaltipan, in order to minimise contamination from overlying oil strata, extensive mudding of sulphur wells has been carried out. Initial results are reported to be favourable with an increasing proportion of output showing a lesser bitumen content. In the past months construction of storage capacity and build-up of stocks has continued. On 30th June stocks amounted to over 200,000 tons in two vats. A third is under construction and a fourth projected, raising total storage capacity to close on ½ million tons.

At San Cristobal additional wells are reported to have been sunk—their total now exceeds 50—and this is expected to be reflected in improved output figures. Stocks at mine and port are reported to total about 80,000 tons.

The port and loading facilities in the free port area of Coatzacoalcos have proved to be satisfactory for vessels up to 10,000 tons drawing 28/30 feet in all states of tide. Both the above named companies have loading and weighing installations capable of handling 1,500 tons per day.

Gulf Sulphur Corporation are expected to start steaming their dome at Las Salinas in October. A two million gallons per day boiler plant is designed to permit initially production at an annual rate of 150,000 tons.

Texas International Sulphur Company who hold large sulphur concessions have not yet formulated exploitation plans, mainly due to recent changes which are reported to have taken place in the company's structure and financial backing.

Texas Gulf Sulphur Company is reported to be making progress towards starting the construction of two small boiler plants on their new concession area adjoining the San Cristobal dome. No official plans have so far been announced.

Sulphuric Acid from Sulphur

THE MODERN TREND IN PLANT DESIGN*

THIS article gives an account of the changes which have taken place in the design of Simon-Carves sulphuric acid plants built during and after World War II to meet the increasing demand for sulphuric acid, the changing pattern of raw material supply, and the growing need for economy in the use of heat and power. The background of technical experience is provided by some 90 Simon-Carves plants built since 1939, or currently under construction, in 18 different countries, ranging in capacity from single units of 300 tons acid (100% H_2SO_4) per day down to 10 tons.

All contact sulphuric acid plants consist essentially of four sections : (a) SO_2 production, (b) gas purification, (c) oxidation, and (d) absorption.

War-time Plants

The war-time plants built by Simon-Carves were all sulphur-burning and of pre-war design in each section. The SO_2 production and gas purification sections comprised respectively a sulphur burner, in which molten sulphur was burned in pre-dried air, and a simple hot gas filter through which the burner gas was passed. Generally a Roots-type blower was used to blow air through a drying tower straight to the burner ; there was no waste heat recovery, the gas from the sulphur burner usually being cooled in two heat exchangers by means of atmospheric air which was blown to waste. The oxidation section comprised two separate cast iron converter vessels with a separate heat exchanger after each, and here, too, the extracted heat was wasted. The absorption section had two absorber towers in series, whether oleum was produced or not, and employed vertical glandless pumps mounted externally to the acid circulation tanks. The coolers were at ground level, and acid flowed through them by gravity.

During the war Simon-Carves built 16 plants in the United Kingdom with individual capacities ranging from 17 to 54 tons per day, and an aggregate capacity of 500 tons. They also built three plants, with an aggregate capacity of 165 tons per day, for the Anglo-Iranian Oil Company (now the British Petroleum Company) at Abadan.

In a few cases limited waste heat recovery was employed, the first attempts being concerned with the use of low-pressure fire-tube boilers operating on the hot air discharge from the various heat exchangers after the burner and the two converters. A further development was direct waste heat recovery by means of a water-tube protected-element type of boiler for cooling the sulphur burner gases. These war-time plants with waste heat recovery were, however, equipped with alternative burner gas cooling arrangements for use in case the boiler was out of action, a fact that shows how cautiously the introduction of waste heat boilers in acid plants was approached.

Since the war Simon-Carves have built only one plant of this design, and this single example was a duplication of an existing plant.

Post-war Plants : 1946-1950

After the war the demand for sulphuric acid increased greatly. In the United Kingdom between 1946 and 1950 Simon-Carves built 14 sulphur-burning plants and one pyrites-burning plant with an aggregate capacity of over 1,000 tons per day and individual capacities ranging from 21 to 240 tons. The average capacity of 72 tons per day was more than double that of the war-time plants. Seven sulphur-burning and three pyrites-burning plants were built abroad, together with one plant using sulphur and refinery sludge acid, their aggregate capacity amounting to 775 tons per day and their size ranging from 10 to 200 tons.

This increase in individual plant size was the most pronounced feature of the sulphur-burning plants of the immediate post-war period. Accompanying features were waste heat recovery, improved conversion efficiency, some simplification of equipment, and increased instrumentation.

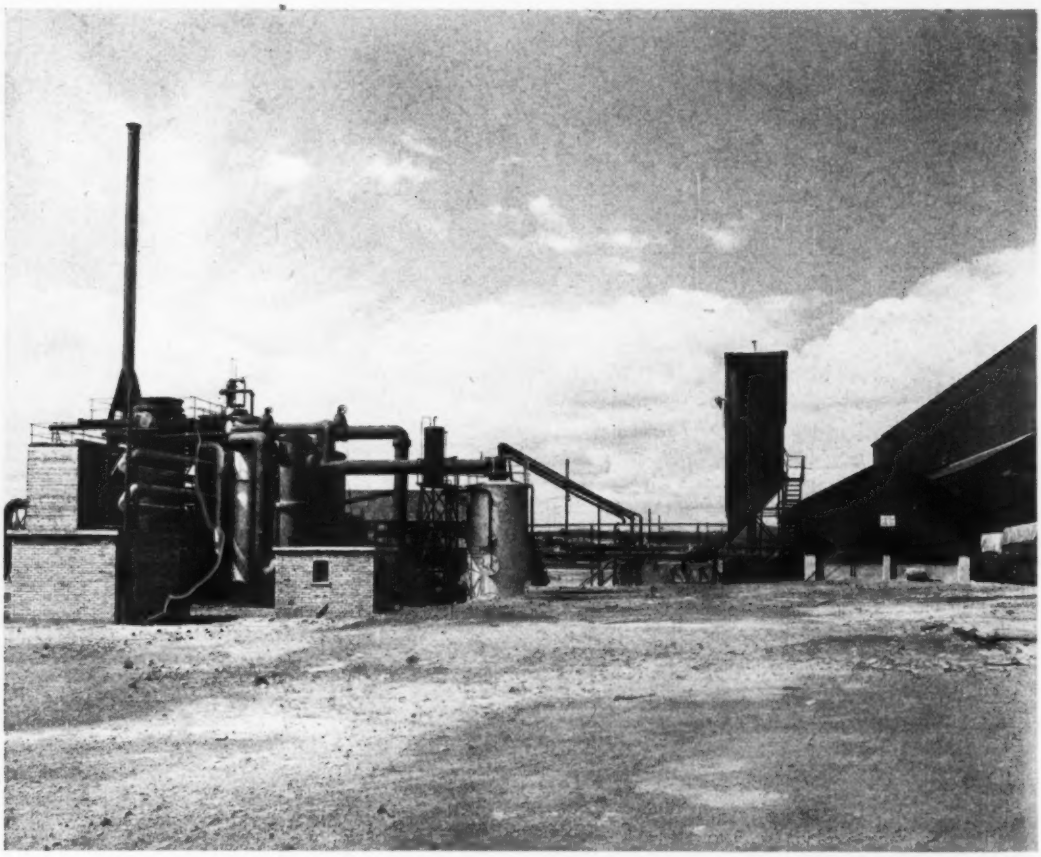
Waste heat recovery not only became almost universal practice but was used on each plant to a much greater extent than on the two

*—We are indebted to Messrs. Simon-Carves Ltd. for the information and illustrations they kindly placed at our disposal.

or three war-time plants equipped with waste heat boilers. The boilers used in these later plants were almost always of the water-tube type, working at pressures of 200 to 400 lb./sq. inch.

Conversion efficiency was raised by using four-pass converters, i.e. by dividing the catalyst into four sections with intermediate gas cooling. Conversion efficiencies of 98 per cent and over became usual. The total quantity of catalyst employed was not increased and the improvement was secured merely by re-distributing the catalyst and installing heat exchange equipment between the passes. In all cases, both during and after the war, Monsanto vanadium catalyst has been used in Simon-Carves plants.

The oxidation unit was considerably simplified by building tall mild steel converter vessels which housed all the catalyst layers one above the other and in some cases also accommodated the heat exchange equipment between the layers. This not only simplified the equipment but also contributed to waste heat recovery by reducing the heat loss from gas mains, duplication of vessels, etc. Plant design was also streamlined in certain other ways. For example, the acid pumps were generally submerged and located inside the acid tanks, the acid coolers were elevated so as to make them self-draining, and acid was pumped through them (instead of flowing by gravity) to obtain better velocities and higher heat transfer



A Sulphur-burning plant of the outdoor type at John Summers & Sons Ltd., Hawarden Bridge Steelworks, Shotton Capacity, 20-25 tons a day (100% H_2SO_4)

rates. Except when oleum was made, a single absorption tower was generally used.

These plants incorporated rather more instruments than their predecessors, partly owing to the wide adoption of waste heat recovery. In addition to temperature, pressure and flow instruments, reliable acid and gas strength analysis meters were normally included.

During this immediate post-war period it became common for sulphur-burning plants to have air blowers which delivered atmospheric air under pressure to the whole of the plant, instead of drawing air under suction through the drying tower and delivering it under pressure to the rest of the plant. This change tended to reduce maintenance costs and encouraged the use of centrifugal blowers, especially in large plants. It is interesting to note that such blowers are now regularly used on nearly all large plants, even when the blower handles gas and air drawn from a drying tower.

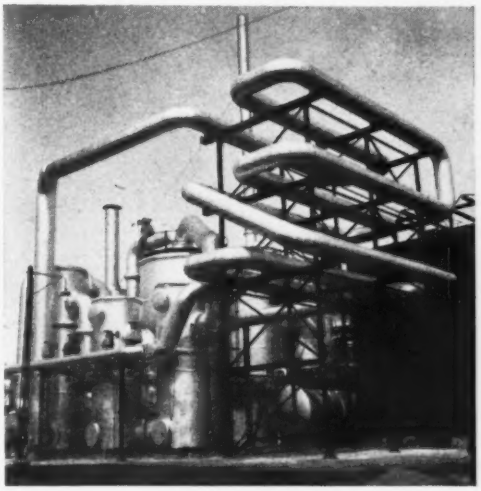
Post-war Plants : 1950 Onwards

The expansion of Britain's sulphur-burning plant capacity was suddenly halted by the sulphur crisis of 1950. The next four years were dominated by the sulphur shortage and by the vigorous measures taken in Britain to substitute pyrites and anhydrite for much of the raw sulphur previously used for acid production.

During this period Simon-Carves built seven pyrites-burning plants in the United Kingdom with a total capacity of 830 tons per day. The pyrites-roasting equipment for these plants was engineered by their subsidiary company Huntington, Heberlein & Co., Ltd., who also built roasters for several other acid plants of 350 tons per day aggregate capacity : Herreshoff roasters, flash roasters and turbulent layer roasters have all been used, each type having its own specific advantages, and each series being in some respects an advance on previous designs.

Another direct result of the sulphur shortage was that Simon-Carves designed and built in conjunction with Imperial Chemical Industries, Ltd., two large plants to produce sulphuric acid and cement clinker from indigenous anhydrite. One of these plants, with a capacity of about 220 tons per day, was built for I.C.I. themselves at Billingham ; the other, with twice this capacity, was built at Widnes for the United Sulphuric Acid Corporation.

During this period one or two British acid manufacturers using sulphur-burning plants of older types found it necessary to have them



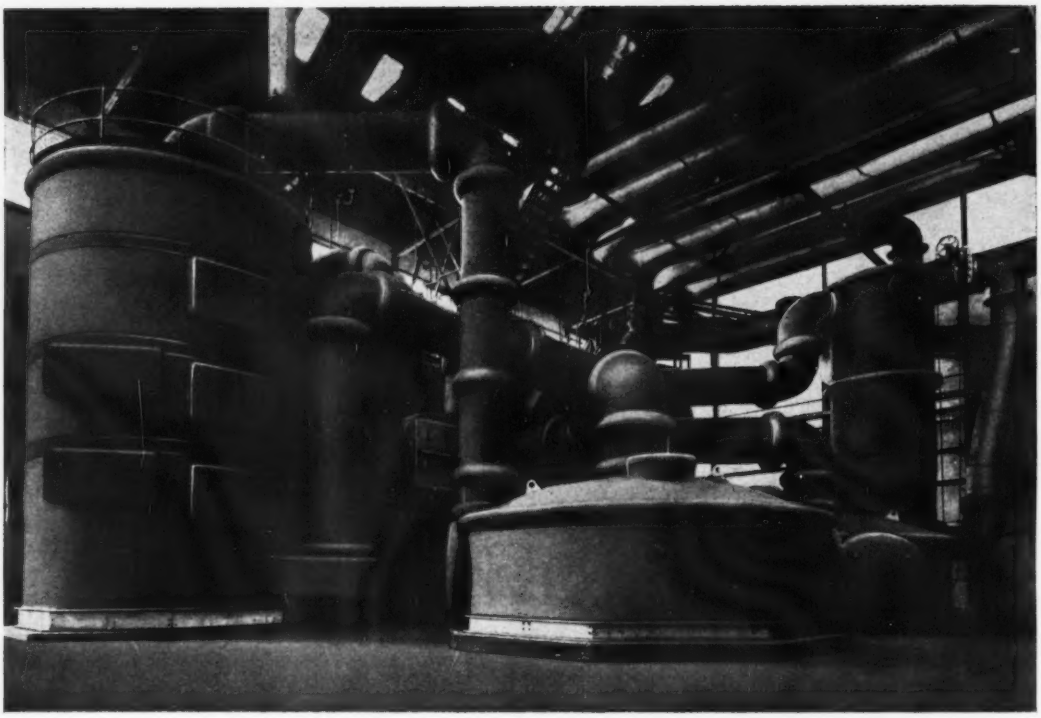
A pyrites burning plant in Portugal. Capacity, 100 tons a day. The converter heat exchanger system is of a type incorporated into many recent sulphur-burning plants to make them suitable for future possible conversion to pyrites.

modernised in order to secure higher conversion efficiencies, and in some cases to take advantages of recent progress in waste heat recovery.

Although the sulphur shortage led to a virtually complete standstill in sulphur-burning plant construction in Britain (except when sulphur recovered from oil refinery gases was available) this did not apply throughout the world. During this period Simon-Carves built six sulphur-burning plants and several pyrites-burning plants in other contries.

Development Trends

During the last year or so the sulphur situation has improved, and it is now generally believed that adequate supplies will be available for at least the next few years. A new impetus has thus been given to the building of sulphur-burning plants both in Britain and



Indoor Sulphur-burning Plant at Courtauld's Ltd., Manchester

abroad, due largely to the lower capital and operating costs of producing acid from sulphur. The present tendency in construction is generally towards larger plants, whilst at the same time there is some demand for small plants of extreme simplicity.

Further changes in design have taken place, the keynote throughout being simplicity, leading to a range of very small plants with a minimum of apparatus. In these, the hot gas filter and all the converter passes are accommodated in a single vertical shell and in many cases, when factories have no use for steam and the units are too small to produce power economically, waste heat recovery is cut down and capital cost reduced by using fire-tube boilers and atmospheric cooling mains. Another example of simplification which has also been adopted on some medium-sized plants is the elimination of at least one heat exchanger by the adoption of air dilution cooling, which has the additional advantage of improved conversion efficiency. There is, however, a limit to the size and pressure of fire-tube boilers, and water-tube boilers of improved design are therefore used for larger plants, especially when power generation from waste heat steam is desired and in such cases pressures up to 650 lb./sq. inch are now practicable.

The possibility of recovering some of the low-grade heat formerly wasted has been further investigated, with the result that recovery, particularly in large plants, has been increased by another 10 per cent or more.

There have naturally been many small changes in detail design which reflect no general trend but are merely the outcome of ever-accumulating experience, but two particular developments have been brought about by (a) the growing concern about atmospheric pollution by industrial effluents, and (b) the changing quality of available sulphur. As regards air pollution, really high conversion efficiency is increasingly essential and the use of four-pass converters is therefore being

continued. Air dilution (which, as already mentioned, contributes to conversion efficiency without complicated additional equipment) is being increasingly adopted. In some plants now being built or projected in Britain the tendency towards simplicity is being partly offset by making provision for the future installation of exit gas scrubbers. The design ot modern sulphur-burning contact plants meets all requirements of the present Alkali Act, but the trend is clearly towards more stringent regulations.

Due to the increasing proportion of dark sulphur being supplied to acid manufacturers the risk of excessive emission of acid gases is growing. In this connection it might be noted that gas from exit stacks may be clearly visible and yet be well within the present requirements of the Alkali Act. Another qualitative shortcoming, experienced in recent years, has been the high ash content of some sulphur consignments, which has caused trouble through excessive blocking of hot gas filters and converters. This has been remedied by filtration, and equipment installed on some recent plants may well become a permanent feature of future sulphur-burning installations, although the major sulphur producers are endeavouring to remedy this nuisance at source. As ash filtration whenever undertaken also tends to reduce the bitumen content of sulphur, it would contribute towards lessening the risk of air pollution.

A feature of all post-war plants, which is also likely to be permanent, is the elimination of buildings. It is now accepted practice to build plants entirely in the open except for such special items as blowers, control room, and perhaps the roasters of pyrites-burning plants. This has contributed to simplicity and thus to reduction of capital cost.

Owing to the heavy post-war demand for sulphuric acid by the fertiliser, rayon, pigment and general chemical industries, many plants have been regularly operated at well above their rated capacity. Much of the progress achieved in the design of successive plants is due to experience gained by observing the behaviour of their forerunners under these extreme conditions. This highly-concentrated post-war experience, gained during a decade in which plants built by Simon-Carves are estimated to account for roughly 80 per cent of the total increase in Britain's sulphuric acid production capacity, is now being brought to bear on an energetic programme of sulphur-burning plant construction throughout the world.

Current Events

UNITED KINGDOM

Anhydrite Plant in Production

The new £3 million plant for the production of sulphuric acid and cement from anhydrite of Solway Chemicals Ltd., of Whitehaven, came into operation early in July. The plant, larger than was at first envisaged, consists of two independent and interchangeable units, one now completed and the other ready for starting up shortly. These have an initial capacity of 100,000 tons of sulphuric acid and 100,000 tons of cement a year. According to a statement by the Chairman, the company's anhydrite mine which serves the plant, and which was originally scheduled to produce 175,000 tons a year, will soon be producing at a rate of 350,000 tons a year—double the amount needed for the proposed annual production of acid and cement. Marchon Products Ltd., the parent company of Solway Chemicals Ltd., will absorb about half the acid produced at the plant for their own use in the manufacture of polyphosphates and detergents, and will also be responsible for the disposal of the remainder on the open market.

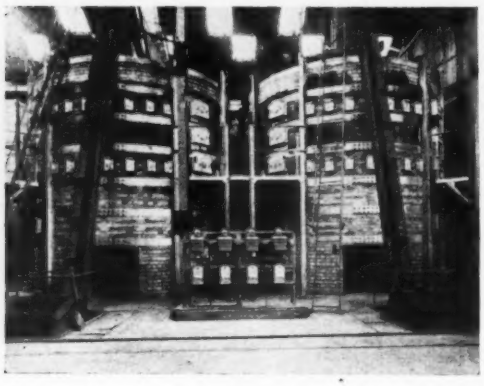
New Sulphur Storage Installation

At their Abbey Mills chemical works, at Stratford, London, Messrs. F. W. Berk & Company are installing new covered storage facilities for about 2,500 tons of sulphur. Sulphur arriving alongside in barges will be unloaded by crane on to a moveable belt transporter which will permit the even distribution of sulphur into storage. In conjunction with this a new sulphur melter with a capacity of twenty-five tons per day and an eighty ton liquid sulphur storage tank are being constructed within the new dry storage area. The discontinuation of storing sulphur in the open will minimise extraneous con-

tamination and wind losses which in the past were not inconsiderable. The new facilities were designed by Messrs. F. W. Berk & Company's engineers in co-operation with the Freeport Sulphur Company. The construction work is being done by Messrs. Matthew Hall & Co., Ltd.

Expansion of Northern Ireland Fertiliser Works

At the Belfast Works of Messrs. Richardsons Chemical Manure Co., Ltd., significant progress is being made in the reconstruction and replacement programme of the company's sulphuric acid and fertiliser manufacturing facilities. At the sulphuric plant, the ten lead chambers have been completely rebuilt and



Harris Pyrites Roasting Furnaces

enlarged, increasing the rated capacity of the plant by more than half, to 21,000 tons (100% H_2SO_4). The corresponding reaction towers comprise four Glover towers and five Gay-Lussac towers. There are also four ammonia oxidation units and ten Ferrari acid pumps. Sulphur dioxide gas is obtained from four mechanical Harris furnaces, of which three roast pyrites and one burns spent oxide. These replace old hand-fired furnaces. The rated annual intake is 10,000 tons Spanish pyrites and 2,500-3,000 tons spent oxide, the latter derived from Northern Ireland, supplemented by occasional consignments from Great Britain. The reconstruction of the superphosphate plant, based on a design by Mr. R. Standaert of Belgium, permits the production of 30 tons per hour with the result that annual output has been raised by about 80% to 47,000 tons a year. The plant is now the biggest of its kind in Ireland.

U.K. Agent for Ente Zolfi Italiani

For the first time since the outbreak of war, a United Kingdom agent has been appointed by Ente Zolfi Italiani to handle the sales of their sulphur in this country. Messrs. Joseph Weil & Son, Ltd., of 39-41 New Broad Street, London, E.C.2, who held the agency before the war, have been re-appointed.

The Ente Zolfi Italiani are presumably anxious to re-establish the traditional sulphur trade between Italy and the United Kingdom and this appointment may foreshadow a more realistic Italian policy bringing their export prices more into line with ruling world levels.

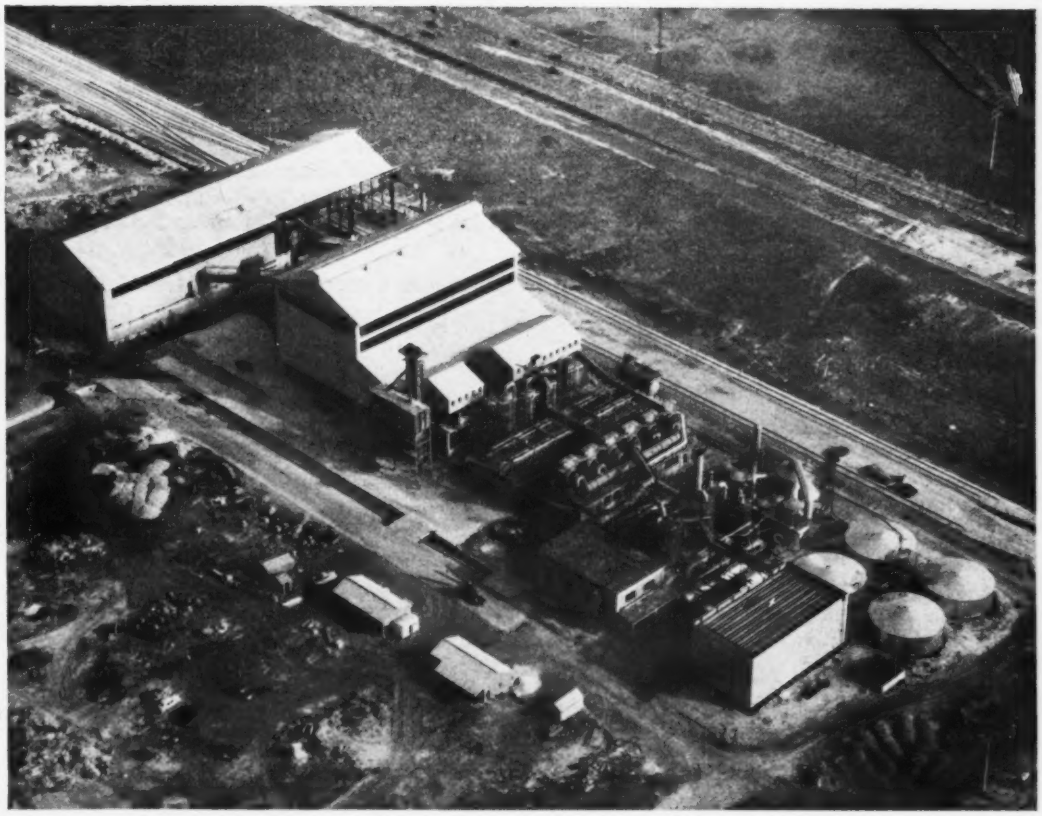
CANADA

Gunnar Gold Mines Ltd.

The company's new acid plant at Beaverlodge, Lake Athabaska, started operating on August 10th. Producing at a daily rate of 140 tons acid (100% H_2SO_4), the plant is reported to be working satisfactorily, exceeding the conversion efficiencies guaranteed by the plant maker. The sulphur requirements of the plant are being supplied by the Shell Oil Company of Canada from their recovery plant at Jumping Pound natural gas field and SO_2 conversion is effected by the contact process. The entire acid output is captive and is used to leach the company's uranium oxide ore output.

New Acid Plant

It has now been confirmed that Noranda Mines Ltd. are to erect a new sulphuric acid plant at Cutler, Ontario. Designed to produce 500 tons a day (100% H_2SO_4) contact acid, the plant will be the largest in Eastern Canada. Based on the use of pyrites concentrates and employing the Noranda sulphur-iron process, it will permit the production, in addition to SO_2 gas required for sulphuric acid manufacture, of about 30,000 elemental sulphur tons a year. The plant is to be built by Arthur G. McKeen Company, and is due to be completed by July, 1956. Its output will meet the acid requirements of uranium producers in the area, notably Algoma Uranium Mines and Consolidated Denison Company.



A nearly-completed pyrites-burning plant for Sulphuric Ltd., at Adelaide, South Australia. With a capacity of 300 tons a day (H_2SO_4). It is the largest single-unit contact plant in the Commonwealth.

AUSTRALIA

Sulphuric Acid Plant for South Australia

The new plant of Sulphuric Acid Ltd., at Port Adelaide started operating during the first week of August. The largest single-unit contact plant in the British Commonwealth, it was built by Simon-Carves Ltd., and is using pyrites concentrates from Nairne as raw material. Designed to produce 300 tons of acid a day (100% H_2SO_4) its output will meet a substantial proportion of South Australia's acid needs for superphosphate manufacture, and will also provide acid for a new unranium project at Mount Victoria. Until recently, local supplies were being supplemented by acid shipped at high cost across the Bass Strait from the plant of the Electrolytic Zinc Company of Australasia at Risdon, Tasmania. It will be recalled that Sulphuric Acid, Ltd., was formed by the Wallaroo Chemical & Fertiliser Co., Ltd., Adelaide Chemical & Fertiliser Co., Ltd., and Cresco Fertilisers, Ltd. The general manager is Mr. Norman B. Walker, formerly manager of Cresco Fertilisers, Ltd.

UNITED STATES

New Sulphuric Acid Plants

The rapid development of chemical industries in the Southern States of the U.S.A. has caused two major manufacturers to extend their sulphuric acid activities to this area.

Plans for the construction of a sulphuric acid plant for *Reichhold Chemicals Inc.*, New York, at Tuscaloosa, Alabama, are nearly complete. Estimated to cost $1 million the plant, built in accordance with plans, design and operational data purchased from Monsanto Chemical Company of St. Louis, Missouri, is

expected to produce 100 tons of acid a day from Frasch sulphur, when it is completed early in 1956.

Most of the output will be used in Reichhold Chemicals' own phenol plant, which is based on a benzene sulphonation process. The rest may be sold locally or elsewhere in Alabama.

Consolidated Chemical Industries Inc., of San Francisco, are to construct a new $2 million contact sulphuric acid plant at Le Moyne, Alabama, about 20 miles north of Mobile near Courtaulds (Alabama) Limited's viscose rayon works. The plant, which is due for completion in June, 1956, incorporates designs by Monsanto for the sulphur burning units, and will be built by the Leonard Construction Company of Chicago, Illinois. It will be supplied with sulphur transported by water to the company's docks on the Mobile River.

About one-half of the acid produced will travel by pipeline to Courtaulds' rayon works. The remainder will be available to other industries in the surrounding area.

The new plant will permit the production of all commercial strengths of sulphuric acid (60° Bé, 66° Bé, 98-99%), and facilities are also to be provided for producing oleum (fuming sulphuric acid).

Consolidated Chemical Industries Inc., who operate ten plants in the U.S.A and three in Argentina, are now reported to be one of the largest sulphuric acid makers in the United States, with works at Houston, Baytown and Fort Worth, in Texas; and at Baton Rouge, Louisiana. The plants supply acid to consumers in a wide range of acid using industries. The company has also recently put into operation two sulphuric acid regeneration plants at Baytown and Houston, said to be capable of producing strong, white acid from spent sludge acid. These units will mainly serve oil refineries in the Gulf Coast area.

Sea Transport of Molten Sulphur

The shipping of liquid sulphur reached a new stage in July when the Monsanto Chemical Company made their first ocean shipment of 2,500 tons, from Freeport Sulphur Company's docks at Port Sulphur, Louisiana, to the Monsanto plant at Everett, Massachusetts. The sulphur was taken in a specially constructed, heavily insulated, hold by the "Chemical Transporter," a 16,000 ton tanker converted by Chemical Tankers Inc., to Newhaven, Connecticut. There it was transferred to a new ocean-going barge, "Chemical Progress." During the 36 hour tow from Newhaven to Everett, the liquid sulphur was kept at a temperature of about 285° F.

Mountain Copper Company Limited

In his statement to the annual general meeting of the Mountain Copper Company Ltd., held in London, the chairman, Mr. R. E. Binns, reviewed progress at the company's pyrites mines in Shasta County, which are among the largest in the U.S.A. Output in 1954 exceeded the preceding five years' average by 18%, in spite of the absence of export demand. The reconstruction programme of the ore transportation system, started several years ago, was completed, with the installation of an automatic ropeway terminal, stockpile station, and automatic railway and loading facilities. Because of excessive production costs, coupled with adverse mining conditions—notably fire hazard—underground development was abandoned some time ago. According to present plans, opencast mining operations due to start at the end of this year are intended to coincide with the cessation of all underground work. The Mountain Copper Company of California, Inc., a subsidiary, has been given a twenty year lease on the Shasta mines with all buildings, plant and equipment, and they will operate the mine on a royalty basis.

Awards for Mining Efficiency

Thirty certificates of management excellence were recently awarded to mining companies for 1954.

Those who received the certificates included the Consolidated Mining & Smelting Company of Canada, Ltd., Montreal, Quebec (metal mining); Freeport Sulphur Company, New York, and Texas Gulf Sulphur Company, New York (both in the group for mining and quarrying of non-metallic minerals, except fuels). The awards were made by the American Institute of Management.

Texas Tidelands Sulphur Leases

At the first major sale held by the State of Texas of sulphur development rights, high bids totalling $8,361,000 were realised. The principal bidder was the Texas Gulf Sulphur Company whose offers for 2,560 acres totalled $5·6 million. From these leases the State of Texas would receive one-eighth of all sulphur produced, double the royalty payable to the Federal Government.

FRANCE

Recovered Sulphur

The petroleum company, Antar-Petroles de l'Atlantique, announced early in August that they are to erect a plant to recover sulphur from refinery gases.

The tonnage the company expect to recover is not at present known, but it will probably be about 4,000-5,000 tons a year, the present output from a similar plant at the Berre l'Etang Oil Refinery of the Cie de Raffinage Shell-Berre.

HOLLAND

New Brimstone Acid Plants

The Royal Sulphuric Acid Works (Koninklijke Nederlandsche Zwavelzuurfabriek v/h Ketjen, N.V.), of Amsterdam, have completed their plans for the construction of a Dutch fl. 7 million contact acid plant based on the use of elemtal sulphur. It is expected that operations will start by the end of 1956 at a rate of 300 tons acid (100% H_2SO_4) per day. At present the company, the oldest acid makers in Holland, use pyrites in their existing plant which, with a daily capacity of about 150 tons, provides a large proportion of the needs of the Dutch acid market, in addition to the company's own requirements. One of their main activities is the manufacture of catalysts for the petroleum industry.

In the meantime, work has started on the construction of a new brimstone burning acid plant for the Eerste Nederlandsche Cooperative Kunstmestfabriek at Vlaardingen. Built by Messrs. Simon-Carves Ltd., it is due to be completed by the summer of next year and its output of 40,000 tons acid (100% H_2SO_4) will be captive for the manufacture of superphosphates.

Hitherto, the company has been using pyrites. The use of elemental sulphur in acid manufacture is a notable departure for the Dutch industry, which, for the past fifty years, has been wholly based on pyrites, mainly of Spanish origin.

ITALY

New Ore Refining Process Proved

At the new refining plant at Perticara, which has been installed for Montecatini by the Impianti Speciali per l'Industria s.r.l. (I.S.P.I.), and which is based on the Masobello refining process, exhaustive trials were completed at the end of July. Using a native ore with calcareous gangue and an average sulphur content of 17·06% sulphur, 80-85% was recovered in the form of 99·9% refined sulphur.

Daily throughput reached 65 metric tons of ore and treatment entailed the use of about 5½ gallons fuel oil and 17 kwh electric power per metric tons of ore.

During the 14 months test period many modifications have been carried out on the above prototype plant. These have been incorporated in a second plant of this type which is due to be completed in November at Saponaro in Sicily. It is expected that this will show better results especially with regard to recoveries.

TURKEY

Ammonium Sulphate from Gypsum

To meet the rapidly growing fertiliser demand, Azot Sanayii T.A.S. (Turkish Nitrogen Industries Ltd.,) are building a new plant at Kutahya, designed to produce 35,000 tons a year of ammonia which, in addition to other products, will permit the manufacture of 60,000 tons a year of ammonium sulphate. It is to be produced by the standard gypsum/CO_2/ammonia method necessitating the use of 100,000 tons gypsum, which will be obtained from extensive deposits—73%-76% $CaSO_4$—at Bicer and Sazilar, some 200 kilometres from Kutahya. The envisaged range of products will require a modest supply of sulphuric acid amounting to 2,500 tons annually. This will be obtained from the by-product acid plant at the Murgul copper smelter.

AFGHANISTAN

Sulphur Deposits

According to the Royal Afghan Ministry of Mines, important sulphur deposits have been discovered in northern and north-eastern Afghanistan and may soon be exploited. The larger deposit, Dar-i-Suf, is situated in the Alburz mountains, 20 miles south-west of Mazar-e-shareef, and is estimated to hold about one million tons of sulphur ore with a sulphur content of 60-70 per cent. Another deposit, on the north-eastern border of Afghanistan in Sangliech, near Chetraal, has not yet been surveyed in detail, but its extent is estimated at about 300,000 tons of ore containing 60 per cent sulphur.

Following the original discovery of the sulphur deposits a technical mission from the U.S.S.R., operating in Afghanistan in connection with economic aid extended to this country by the U.S.S.R., showed interest and arranged for ore samples to be examined.

It appears that the ore was satisfactory, as the Afghan Ministry of Mines have now announced that negotiations have started regarding the export of the output of sulphur ore from the Dar-i-Suf deposit to the U.S.S.R.

COLOMBIA

Increased Sulphur Production

Production of sulphur by Industrias Purace S.A., the only producer in the country, totalled 2,610 metric tons in the first six months of 1955, and the expected output for the year of about 6,000 tons compares with 4,872 metric tons produced in 1954. The entire output is derived from autoclave refining, and three new and improved autoclaves which are planned to increase production still further are now being built locally.

The company's output meets internal requirements, which, showing a steady increase, amounted to over 400 tons per month during the first half of this year. In view of high import duties on all but a few special grades of sulphur, the domestic market is fully protected, and internal prices are little affected by the lower level of world prices.

MEXICO

Record Sulphur Well

In a recent announcement to stockholders, Gulf Sulphur Corporation stated that in the course of development of their Las Salinas dome one of the wells cored 695 feet of sulphur bearing limestone. This is believed to be one of the largest wells drilled in Frasch sulphur operations. Exploitation work to date on the 7,414 acre property of the company disclosed sulphur bearing caprock varying in thickness from 20-565 feet containing 8·9%—34·1% sulphur (by weight) indicating reserves of some 11 million tons.

New Acid Plant

Plans have been announced recently by Industrias Quimicas de Mexico, S.A., for the construction of a sulphuric acid plant to be located in the State of Michoacan. A suitable plant-site is at present being selected and construction, due to start without delay, is expected to be completed before the end of next year. The new plant, which is to be based on the use of indigenous Frasch sulphur, is designed to produce 100 tons acid (100% H_2SO_4) daily by the contact process.

In 1953 total acid output in Mexico amounted to 102,502 metric tons of which 68% was brimstone acid and the balance by-product acid from lead/zinc smelters.

PERU

Sulphur in Rubber Manufacture

The newly-established Lima Rubber Company, which is an associate of the International B.F. Goodrich Company of Akron, Ohio, U.S.A., will use some 30-35 tons of refined sulphur a year in tyre and rubber manufacture at its new plant in Lima. The plant, designed by B. F. Goodrich engineers, will use rubber from eastern Peru,. The sulphur will originally be obtained from the United States. After the project is under way, however, the local company will organise supplies from domestic sources provided these are competitive or, if necessary, by import if regulations permit.

Statistical Appendix

Yugoslavia

EXPORTS OF PYRITES AND PYRITES CONCENTRATES

Thousand metric tons

	1949	1950	1951	1952	1953	1954
Austria	11	93	11	8	16	19
Hungary	6	—	—	—	—	8
W. Germany ...	3	1	111	132	43	86
U.S.S.R.	61	—	—	—	—	—
Czechoslovakia ...	78	—	—	—	—	—
Italy	—	1	1	1	7	10
Switzerland	—	81	19	—	—	—
Denmark	—	—	19	—	—	—
Netherlands ...	—	—	—	9	—	—
Belgium	—	—	—	—	2	8
U.K.	—	—	—	10	3	—
	159	176	161	160	71	131

SULPHURIC ACID PRODUCTION

Thousand metric tons 100% H_2SO_4

1939	14	1950	40
1945	26	1951	No data
1946	26	1952	32
1947	37	1953	40
1948	46	1954	60
1949	45		

IMPORTS OF ELEMENTAL SULPHUR

Thousand metric tons

1949	4.6	1952	5.4
1950	4.4	1953	4.0 est.
1951	1.4	1954	3.0 est.

Spain

PYRITES EXPORTS

Thousand metric tons

Average	1891 - 1900	946	Average	1941 - 1950	672
	1901 - 1910	2,095		1951	1,540
	1911 - 1920	2,357		1952	1,682
	1921 - 1930	2,474		1953	1,192
	1931 - 1940	1,990		1954	1,455

O.E.E.C. - 1954

	Native (x) & Recovered Sulphur	Sulphur in Pyrites	Other Forms	Total	Elemental Sulphur	Sulphur in Pyrites	Other Forms	Total
	PRODUCTION				*CONSUMPTION*			
	Thousand metric tons							
Austria	—	—	62.3	62.3	23.4	33.9	54.5	111.8
Belgium	0.4	—	2.6	3.0	50.5	176.0	132.2	358.6
Denmark	—	—	1.6	1.6	0.5	63.4	0.2	64.1
Eire	—	—	0.6	0.6	0.2	26.0	0.6	26.8
France	3.8	124.9	48.1	176.8	154.6	390.1	90.5	635.2
W. Germany ...	70.0	214.0	84.0	368.0	81.0	640.0	140.0	861.0
Greece	2.5(x)	101.2	8.5	112.2	12.1	41.5	3.7	57.3
Italy	204.0(x)	554.3	95.2	853.5	107.3	582.9	83.2	773.4
Netherlands ...	9.4	—	6.8	16.2	3.2	201.5	19.1	223.8
Norway	100.7	220.7	3.4	324.8	25.1	51.9	18.5	95.5
Portugal	16.4	268.4	—	284.8	12.0	31.1	—	43.1
Sweden	27.9	196.9	31.2	256.0	65.7	241.2	—	306.9
Switzerland ...	—	—	0.8	0.8	35.5	22.0	0.2	57.7
U.K.	41.5	1.6	384.9	428.0	375.7	241.8	438.9	1,056.4
TOTAL ...	476.6	1,682.0	730.0	2,888.6	946.7	2,743.3	981.6	4,671.6

Courtaulds'

'COURLENE' Regd.

for protective clothing

In industries where contact with corrosive chemicals is likely, or where cleanliness is necessary and contamination a hazard, 'Courlene' — Courtaulds' polythene yarn — plays one of its most successful roles.

'Courlene' is tough and flexible; but even more important, it is exceptionally inert and resists attack by most chemicals, including acids, alkalis and solvents at normal temperatures. It is resistant to solutions of organic salts. It absorbs oil slowly. It resists staining. It is easily cleaned and easily sterilized. Moreover, boiler suits, protective vests, overalls and laboratory coats woven with 'Courlene' are always comfortable to wear.

With these virtually hand-picked qualities, it is hardly surprising that 'Courlene' yarn is proving itself equal to any — and better than most — for the manufacture of protective clothing.

'COURLENE' Regd.

Courtaulds' polythene yarn

Courtaulds Limited, Foleshill Road, Coventry.